OVERCOMING BARRIERS TO IVHS-
LESSONS FROM OTHER TECHNOLOGIES

TASK A REPORT

Prepared for the Federal Highway Administration

by The Urban Institute
with
Miller, Canfield, Paddock and Stone
MTA/EMCI

Contract DTFH61-93-C-00025
UI Project No.: 06351
February 24, 1995

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ACKNOWLEDGEMENTS

This project, which is still in progress, is being performed for the Federal Highway Administration (FHWA) by The Urban Institute, the Prime Contractor. Subcontractors are Miller, Canfield, Paddock and Stone, and MTA/EMCI. FHWA's Contracting Officer's Technical Representative is James Saklas. Technical oversight for this project at The Urban Institute is being provided by Joshua Silver.

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EXECUTIVE SUMMARY

CONCLUSIONS AND RECOMMENDATIONS

This report provides an examination of a broad range of institutional issues that illuminate various potential barriers to the deployment of two forms of Intelligent Vehicle Highway Systems (IVHS): Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS). Institutional barriers are construed very broadly and include:

- Potential serious obstacles to deployment.
- Factors that could delay deployment for a either a short or long period of time.
- Impediments to fully realizing all the private and public benefits that might ultimately accrue from deploying ATMS and ATIS.

This report explores institutional barriers by proceeding along five lines of inquiry:

(1) Identifies the institutional setting which includes certain features that in and of themselves can potentially become barriers to fully successful deployment.

(2) Explores dichotomies such as public versus private and centralization versus decentralization that reflect tensions or conflict that could give rise to institutional barriers.

(3) Examines sources of institutional fragmentation.

(4) Assesses whether the timing (adhering to a critical path) is crucial to successful deployment, and whether there are any inherent problems of different phases of deployment ranging from the research, testing and design phase, to construction and manufacturing, to operations and maintenance.

(5) Evaluates other potential barriers based upon existing literature, interviews and the public docket for U.S. Department of Transportation report to Congress on non-technical constraints to the deployment of IVHS.

The following are the main conclusions and recommendations resulting from each of these avenues of inquiry.

There is no greater barrier to implementing IVHS than costs and the willingness of either consumers or taxpayers to cover the costs. The private and public sectors can each attempt to saddle one another with a greater share of the costs, but in the end someone will pay and perhaps not enough to achieve full deployment. The private sector will pursue IVHS only if consumer demand and protfis are in clear view, otherwise the government must be prepared to pay. Consumers could rebel against IVHS ifit requires people to pay for the use of services to which they feel entitled (Le. toll roads instead of free roads or fees for traveler information developed with public funds).

Recommendations:

- Government together with the private sector needs to undertake a thorough and defensible study not only of consumer demand and willingness to pay but also taxpayer demand and willingness to pay under a range of different assumptions about public and private sector roles in deploying IVHS.

- An accurate assessment of capital, operating and maintenance costs is essential, as well as external and non-quantifiable costs. Achieving consensus among local governments to implement ATMS or ATIS in a region is likely to depend on an acceptable formula for allocating costs between the private and public sectors and among all localities.

- The key to achieving an equitable allocation of costs will be a full understanding of how marginal costs arise and the distribution of benefits. Costs should be allocated to the extent practical according to the marginal cost generated and otherwise according to the benefits received. private benefits will generally be in terms of profits and public benefits are most likely to be in terms of reductions in congestion, pollution, and accidents.

- Ultimately, the government's principal protection for the IVHS program, given the unpredictability of private sector behavior, is to (1) either define the program to survive with minimum private investment or (2) design the program to limit the risk of private firms to an acceptable level.

ATIS and ATMS deployment is likely to be hampered by "chicken and egg problems": (1) automobile manufacturers may wait to install ATIS equipment with communications interfaces until telecommunications companies provide roadside infrastructure such as beacons (or wireless technology emerges) and vice versa, (2) Telecommunications companies may not supply the transmission medium for ATIS except as a part of the national information superhighway, until ATIS data bases are developed, and vice versa.

Recommendation:

- Government should, as soon as a national system architecture is developed, create strong financial incentives for the telecommunications industry to provide the roadside infrastructure to support ATMS and ATIS, where it has not already been developed, provided wireless technology does not obviate the need for roadside infrastructure. In some cases wireless may have lower initial costs than wire communications and could speed up deployment. Creating such incentives may entail ensuring that ATMS and ATIS roadside communications are at least as profitable as providing telecommunication linkages to other sectors of the economy such as large businesses, national research centers, hospitals, and homes.

A failure to account for the critical path needed to implement ATMS and ATIS could pose a significant barrier to deployment. For example, ATIS will most likely, but not necessarily, depend upon real-time traffic information from an ATMS, and thus cannot be efficiently implemented until an ATMS is in place.

Recommendation:

- If it is not part of the national system architecture effort or other studies, the federal government should perform an in-depth study of the critical path for stand-alone and integrated ATMS and ATIS deployment.

One of the most difficult set of barriers to overcome are differences in work culture among organizations, the competing interests of multiple jurisdictions within a metropolitan region or state, turf and fragmentation within organizations, the hierarchy of government, and different policies among nations engaged in IVHS.

Recommendations:

- The IVHS community should build upon the already very successful coordination occurring through IVHS America, the Federal Highway Administration, and other organizations. Such activities as international coordination with Japan and Europe, the IVHS America's outreach program, the consensus building effort of the national system architecture project, establishment of local IVHS America chapters throughout the United States, multistate and regional/local corridor coordination projects, and multi-jurisdiction regional incident management teams should be continued. Efforts to achieve coordination should not be for coordination sake, but to ensure the success of specific actions resulting in eventual deployment. For example, specific operational tests in conjunction with each user service described in the IVHS program plan should be the focal point for specific, targeted coordination. Priorities for coordination activities should be set and based upon the greatest benefits in terms of fostering deployment goals in relation to the effort expended. Successful coordination efforts should be widely publicized and replicated wherever possible.

- Coordination among different countries engaged in IVHS activities is important if the goal of realizing maximum public and private benefits is to be achieved. Development of international standards for equipment, digital maps, and telecommunications that apply to ATMS and ATIS will result in manufacturer and telecommunication suppliers being able to achieve economies of scale, enlarge profit opportunities within the global market place, and increase the likelihood of interoperability of IVHS throughout the world.

- The federal government should exercise its authority under the interstate commerce clause of the constitution to require public agencies and authorities managing both toll and free roads in interstate corridors to fully cooperate in order to achieve the full benefits of ATMS and ATIS when it is implemented in those corridors. The federal government should set specific user (customer) oriented performance objectives for ATMS and ATIS and require that agencies responsible for managing the facilities in those corridors meet those objectives.

- When all levels of government must be involved in IVHS decision making, the federal government should pursue strategies that flatten the decision making process among different levels of government. One approach might be to pursue concurrent decision making by representatives of all parties meeting in a room, instead of sequential

decision making. Another approach is to place the greatest decision making authority in the hands of the level of government that internalizes the most important competing interests. This will normally be the Metropolitan Planning Organization (MPO) which internalizes local government jurisdictions, and states, which internalize competing substate interests. This level of delegation within the hierarchy of government is consistent with the responsibility of MPOs and states in formulating long range plans and TIPs required under the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA).

- The federal government should find delicate ways to strongly encourage state, local and regional transportation agencies to overcome organizational fragmentation and turf that stands in the way of their effectively addressing transportation needs, whether through advanced technology or by other means. Some integrative strategies that might be welcomed at lower levels of government are:

  - Provide financial incentives for creating common geographic information system platforms and locational reference systems (both coordinate and elapsed distance with convertibility and ground truth) at the state and regional level and which are consistent with national standards for digital maps used in ATIS.

  - Provide financial incentives for accelerating the deployment of broadband digital communications infrastructure for use ***within*** public agencies and that is integrated with the emerging national information superhighway and also serves the elements of ATIS and ATMS within the domains of public agencies. Internal telecommunications networks can facilitate sharing of data and teleconferencing, which tend to break down organizational barriers.

- IVHS America should provide a pool of expert, proven facilitators that can assist in IVHS decision making and help bridge differences among widely varying vested interests in the following contexts:

  - Negotiations involving parties from two or more of the following sectors: public, private, academic, national laboratory, defense, industry associations and other coordinating and public interest groups
  - Regional decision making
  - Operational tests and specific deployment projects

- The government should look to recommendations from subsequent phases of this study regarding how to overcome the institutional barrier posed by multiple jurisdictions. Advisability of such strategies as franchising, competitive joint ventures, contracting with the private sector to design-build-operate-maintain ATMS and ATIS, and regulatory and cost-sharing/pricing strategies will be addressed.

Recent experience with the inability of local agencies to operate and maintain advanced traffic signal systems, suggests lack of funds and other resources for maintenance and operations is one of the most severe potential problems concerning successful implementation of ATMS.

Recommendation:

- The federal government should take strong measures to ensure that funds and staff are available to ensure the continued maintenance and operation of ATMS and ATIS. Steps include selecting a national system architecture that fully takes into account lifecycle costs and is conducive to reliable operations and maintenance; eliminating the requirement that procurement contracts for deployment of IVHS should be based on the lowest bid; setting maintenance standards and auditing compliance with those standards; encouraging quality assurance and control in manufacturing and installation and the use of automated diagnostics and repairs; providing financial support to levels of government responsible for maintenance and operations and not leaving these responsibilities entirely to lower levels of government: and ensuring adequate training and education to support maintenance and operations. More detailed recommendations are found in The Urban Institute's report, IVHS Staffing and Educational Needs.

Most MPOs have limited staff to comply with all the regulations under the ISTEA and to perform credible analysis of the pros and cons of ATMS and ATIS projects in comparison to other transportation improvement projects. This could prove a significant hindrance to making the case to include ATMS and ATIS in a Transportation Improvement Program (TIP).

Recommendation:

- The federal government should carefully monitor the degree to which MPOs are able to comply with ISTEA regulations, including evaluation of IVHS and other projects being examined for possible incorporation into the TIP. The federal government should encourage MPOs to develop an approach to complying with ISTEA regulations that integrates the management systems and planning and air quality conformity procedures as much as possible. This should help to keep staff and planning costs to a minimum. The federal government should also provide technical assistance through training, guidelines, and development of improved analytical methods and easy-to-use software. A last resort would be to increase funds for regional planning.

TIPs developed at both the state and metropolitan level containing ATMS and ATIS projects are vulnerable to legal action concerning compliance with environmental related reguhuions.

Recommendation:

- The federal government should strongly encourage states and MPOs to analyze the environmental ramifications of major actions and transportation improvement programs implementing ATMS and ATIS. To facilitate this analysis, the federal government should conduct a detailed environmental evaluation of alternative project and programmatic ATMS and ATIS concepts that can serve as the basis of state and regional environmental analysis.

Political opposition to IVHS is likely to arise from those who perceive themselves as non-users and as potentially being harmed by significant governmental expenditures on IVHS

Recommendations:

- IVHS America should establish two additional categories of advanced transportation systems, Advanced Bicycle Transportation Systems (ABTS) to serve bicycle interests and Advanced Transportation Systems for Pedestrians (ATSP) to serve pedestrian interests. In fact there are a large number of real safety and travel issues that warrant establishing these two types of advanced transportation systems and giving them a high profile similar to other systems such as Advanced Public Transportation Systems.

- Airline, railroad, and waterborne transportation interests should be invited to participate in IVHS America, if they have not been already, and constructive approaches to addressing intermodal interfaces should be identified that are mutually beneficial to all the modes involved.

There is a significant risk that the IVHS community will not pursue concerted efforts to serve low income and unprofitable sectors of the economy where large public benefits may accrue. This could turn into a severe institutional problem just as Congress could hold rapid development of a national information superhighway hostage to agreement to provide universal access.

Recommendations:

- The U.S. DOT and IVHS America should develop explicit policies toward universal access by taking into account the benefits of access to all versus economic inefficiencies of cross-subsidies or other means to pay for it. The IVHS community might take its cue from the debate on the topic currently taking place in the U.S. Congress regarding the national information superhighway.

- Electronic toll collection should be imposed only where there is strong community support or there are alternative free routes. However, broad social goals of reducing congestion and air quality externalities would be well served by congestion pricing in urban areas. If the public can be convinced that the efficiency gains of electronic toll collection combined with congestion pricing outweigh the equity problems, then these elements of IVHS would be desirable, provided other social issues are satisfactorily resolved such as protection of privacy.

Failure to protect personal privacy could derail specific ATMS or ATIS projects or even seriously injure the entire IVHS program. There is considerable danger that vehicle location information regarding private vehicles either alone, or coupled with other sensitive data bases might be subject to misuse by law enforcement agencies, private investigators, insurance companies, credit bureaus, and others. The public might not stand for any further erosion in privacy.

Recommendations:

- The interests of the IVHS community and the law enforcement community may well be different. It will be easier to gain public approval for IVHS without carrying the "excess baggage" of public sensitivity to law enforcement applications.

- Apart from law enforcement concerns, there is considerable potential for abuse of private information by commercial entities. Privacy concerns can be divided into two categories: information privacy issues and surveillance issues, the latter probably being more difficult to resolve. Measures for addressing both concerns should be taken.

- IVHS will take a long time to approve and to deploy. Any attempt at "window dressing" for the public concerning the privacy issue will fail under sustained scrutiny. Candor will be much more successful in the long run.

- The IVHS community should investigate technologies that might achieve the principal benefits of IVHS without collecting personal data. If the data are not collected in the first place, the public will not be concerned that safeguards might be eroded in the future.

- Data that are collected should be treated in confidence and the means for that treatment should be negotiated in advance with the public actively engaged.

- Individually identifiable data should be used only for the narrowest of purposes (e.g. billing for a particular service) and only if the customer authorizes the specific use. In short IVHS should be ***voluntary —*** the customers should be able to make their own tradeoffs of information for benefit received at the time of the actual transaction.

- Data maintained in aggregate form (e.g. in the manner of census data) should be usable without restriction.

Intellectual property rights for software, patents, copyright material, etc. are potentially a significant barrier to rapid deployment of IVHS. The positions of the public sector, which generally wants to retain the rights to intellectual property developed or implemented with public funds, and the private sector, which wishes to protect property interests, may be too far apart on this issue.

Recommendations:

- Apportion intellectual property rights in relation to the actual costs incurred by the government and private parties and assure the private firm a reasonable return on its investment.

- Give appropriate consideration of the risks incurred by the private firm in developing intellectual property in drawing up a contract.

- Identify ways to avoid creating with public funds a de ***facto*** technological monopoly for a private firm.

- Try to apply a uniform nationwide process for the entire IVHS program to avoid the confusion of hundreds of different policies in different states and regions

- Distinguish between technical standards, widely available and based on an open architecture, and intellectual property rights that underlie a particular vendor's ***implementation*** of those standards.

- Use escrow accounts for software partially developed with government funds (i.e. place an archival copy of software and documentation in a safe deposit box). This would allow government access to the software in the case a private firm defaults on its obligation under a contract.

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Centrally controlled ATMS must serve decentralized decisionmaking which creates a dynamic tension that if not properly handled could become a barrier to deployment.

Recommendations:

- The federal government should always support decentralized approaches to ATMS and ATIS implementation except in clear instances where individual travelers or shippers, through myopic decision making, cause system benefits to be less than they would be if there were centralized control. However, it is crucially important for local communities and businesses to be fully educated as to why travel guidance that may not appear optimal from a local perspective, is desirable.

- There should be a careful assessment of which functions of traffic management centers in metropolitan regions should be centralized. Functions that should be examined include collection and dissemination of traffic data; provision of route guidance information through in-vehicle routing devices, variable message signs, and highway advisory radio; signal pre-emption for high occupancy vehicles; and emergency response and incident management.

- The emergence of distributed data bases attached to a rich, extensive and highly decentralized telecommunications infrastructure, and large number of potential future providers of traveler and shipper information suggests that in the mid- to long run ATIS should be provided in a decentralized manner and should be offered in the competitive market place, including competition between the public and private sector. However, in the short run, in order to achieve rapid deployment in the face of global competition and to obtain economies of scale, it may be warranted to accelerate deployment with a combination of financial incentives and placing responsibility for establishment and centralized management of regional ATIS in the hands of one or a few public or private organizations through operational tests, turnkey contracts, franchising, etc. Arrangements such as franchising should be competitively bid at the outset and competitively rebid, say every ten years.

There are conflicting pressures favoring on the one hand a laissez-faire (Le. competitive) approach and on the other hand a regulated approach to deployment of IVHS. Satisfactory resolution of this conflict is necessary for successful deployment.

Recommendation:

- In the long run, monopoly or oligopoly provision of services and facilities should be considered for a limited class of IVHS markets, probably those involving the traffic management center and the provision of roadside telecommunications infrastructure (instrumented roadways or toll facilities). Justification for restricted markets in the long run include scarcity of the public commons such as the radio frequency spectrum, the desirability of achieving economies of scale, the importance of avoiding wasteful duplication of rights-of-way for public utilities, and the need to reduce risk which is a roadblock to deployment. Even in those cases extreme caution should be exercised due to the risk of forgoing the benefits of competition.

Users and managers of ATMS and ATIS are likely to make far less than optimal decisions that could hamper IVHS deployment because of the difference between the "perceived" and "real" price of transportation choices. This difference arises in a variety of ways in various contexts due to the difference between (a) the "money price" people pay out-of-pocket, (b) the "shadow price," which largely consists of travel time costs that currently serve to ration scarce highway capacity, and (c) the "real" price equal to the true social cost including air pollution and other externalities. Failure to properly account for or resolve these differences could hamper IVHS deployment.

Recommendation:

- ATMS and ATIS should communicate and provide route guidance wherever possible based on the true combined travel time and money costs to motorists and shippers. While congestion pricing using electronic toll collection is one such strategy to better communicate the relative costs of travel options to transportation users, it has not yet proved politically acceptable. In addition, there may be creative strategies for communicating other external costs not normally taken into account in trip and route decision making such as air pollution costs. For example, one might communicate the relative emission levels from different modes to travelers when they access pre-trip planning information from an ATIS.

Conflicting pressures for top-down versus bottom-up planning, design and implementation for IVHS could impede deployment.

Recommendations:

- Avoid mandating a single design for IVHS. The National IVHS System Architecture effort which is emphasizing an open architecture, appears to be taking this desirable approach.

- Establish national standards and protocols flexible enough to accommodate a wide variety of equipment and telecommunications.

- Fully take advantage of the flexible funding provisions of ISTEA to ensure local, regional and state government can meet their own needs.

- Use block grants or other discretionary subsidies as appropriate to enable local and regional agencies to tailor IVHS to the idiosyncrasies of their housing and job markets.

Mishandling of technical standards could significantly hamper the deployment of IVHS. It is widely acknowledged that establishment of technical standards is a two-edged sword Standards set too early can foreclose innovation. Stardards set too late can result in the haphazard development of products of so little uniformity that not enough consumers buy any particular type to result in profitable markets.

Recommendation:

- The federal government should support early open international standards designed to allow for multiple suppliers and alternative implementations.

I. CHAPTER ONE — INTRODUCTION

IVHS has been born of history, opportunity and fear. IVHS did not suddenly thrust itself unexpectedly on the transportation landscape. History, including visions of the future dating back to General Motors exhibit at the 1939 Worlds Fair, has helped to nurture the sudden growth in activity in IVHS. Partially automated traffic signal systems already installed and navigation systems such as Loran were harbingers of IVHS.

Startling technological advances in computers, telecommunications, navigation, and miniaturization have spawned enormous business opportunities that have catalyzed the IVHS industry. Tiny microprocessors with enormous speed can provide part of the "Intelligence" for IVHS. Digital communications, voice technology, and computer graphics, coupled with GPS and map matching techniques have made real time route guidance and navigation possible using equipment installed in the vehicle.

And fear has been no bystander. Competitive threats of European and Japanese automakers and globalization of markets have caused the U.S. government, partly at the urging of the automobile and other related industries, to embark on an industrial policy to foster deployment of IVHS in the United States and maintain and enhance this country's competitive position throughout the world. Major structural change resulting in the downsizing of the defense sector, and massive layoffs by large industrial employers have amplified the fear. There is another fear as well: traffic is expected to double in the next twenty years and the transportation system could choke on congestion. The costs of highway expansion and the expected resistance of environmentalists to a major new program of highway construction leave government few reasonable alternatives. One of these is to fully explore the possibility of applying advance technology to increase throughput of people, goods and traffic, as called for under the 1991 Inter-modal Surface Transportation Efficiency Act (ISTEA). Throughput must be increased while avoiding compensating increases in induced traffic. Air quality must improve at the same time.

There is a sense of urgency concerning the deployment of M-IS. ISTEA provides $660 million for research and development and operational tests over a six year period. The Clinton Administration recently augmented this funding with an additional $355 million to foster a new high-tech, high wage industry. A large national investment is being made in IVHS and the politicians, program managers, and key players in private and public industry expect results. While there is room for much experimentation, there is little margin for failure. If just a few highly visible IVHS operational tests go awry, it could seriously hamper the rapid deployment of IVHS, just as a series of overruns and failures have undermined the U.S. space program. Moreover, if private and public managers of the various elements of the IVHS program are not watchful enough, technical or non-technical barriers could frustrate deployment and seriously retard, limit or even doom the effort.

Conventional thinking about the deployment of new technological systems sees the principal impediments to deployment as consisting of costs, technical feasibility, benefits and performance. To private industry, costs are typically investment, manufacturing, and marketing costs. But to the public sector costs include unwanted economic, social, and environmental side effects. Private industry, which is usually in the vanguard of technological innovation compared to the public sector, is more likely to appreciate where the boundary of technological feasibility lies. The private sector construes benefits primarily in terms of profits and market opportunity,

whereas the public sector sees benefits in terms of reduced congestion, accidents, pollution and energy consumption. The private sector is more likely to be concerned about its performance in satisfying customer needs, measured in terms of sales, market share, net earnings and stock market share price. The public sector is more likely to look at public sector performance indicators such as the volume-to-capacity ratio on specific roads, reduction in fatalities and personal injuries, and changes in pollution emissions and concentrations.

Success in the deployment of IVHS means maximizing private and public benefits in relationto costs. This is not a facile or trivial definition. Widespread adoption of IVHS by both motorists and commercial transport will occur only if private industry can fully realize the latent profit opportunities in IVHS and the public sector can fully realize the potential of IVHS to reduce congestion, accidents, pollution and energy consumption. One of the most important potential barriers to deployment is the mismatch between the respective benefits, costs, and implementation responsibilities of the private and public sector. The fundamental challenge to the IVHS community is to breach the various divisions that currently result in this mismatch so that the private and public sectors have a common vision, a shared purpose, and make decisions based upon the same calculus of benefits and costs. Much progress has been already made in this regard. The creation of IVHS America has forged a private/public partnership that has a common strategic vision and implementation plan. The operational tests already underway have brought the public and private sectors together in many teams, and the federal effort to develop a national system architecture will seek to merge public and private perspectives into a common one.

Many in the IVHS community have remarked that the principal barriers to rapid and successful deployment are not technical but institutional. This report documents the results of the first of three fundamental tasks of a study conducted by the Urban Institute for the Federal Highway Administration entitled "Overcoming Barriers to IVHS: Lessons from Other Technologies." The first task is to explore, based on a combination of the literature and interviews, potential institutional barriers to the deployment of IVHS. Subsequent tasks concern inferring lessons from the deployment of advanced technology in other industries (e.g., cable television and cellular telephone), and assessing the suitability of alternative models of public and private participation in the deployment of IVHS.

A. Focus on ATMS and ATIS

The main focus of this study is Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS). In initial deployment, ATMS and ATIS are likely to have different technological characteristics which influence the institutional barriers to which they are susceptible. Over time, however, the technological characteristics will tend to converge, especially as ATMS and ATIS are integrated.

ATMS will be the foundation of much IVHS. ATMS typically includes a traffic management center, surveillance of vehicles, and real-time control of signals, freeway ramp meters, changeable message signs, and highway advisory radio; dispatching of incident management vehicles; and integration of electronic toll collection in some regions. Traffic signal controllers do not conform to a single national standard and currently tend to be of two different types, NEMA (National Electrical Manufacturers Association) or 170 controllers. Advanced controllers, with a bus structure for handling communications with the various devices and processors used in ATMS (loop detectors, video cameras) are likely to replace the existing

controllers. There will be a tendency of ATMS to exert centralized control over the traffic, although, as discussed below, there are strong reasons for control to be higbly decentralized. Current communications technology relies on in-ground wire systems, usually fiber optic but often coaxial, which spread like tentacles from the traffic management center. In final deployment, the communications may be fiber optic cable or other wide-band media, wire or wireless, supplemented by other telecommunications methods such as spread-spectmm radio. Thus, over time, as broad-band wireless technology is introduced, in some regions there may be less reliance on in-ground wire systems, and more on wireless communications.

ATIS will provide information for optimally planning a trip and for revising a trip once enroute based upon real-time transportation conditions. People will be able to access trip planning information in their homes and businesses and while on the move by such devices as in-vehicle equipment, personal digital assistants, computers, interactive TV, and telephone. In-vehicle equipment will convey route guidance information to drivers. Integrated digital maps and electronic data bases will be the primary source of information along with real-time traffic condition information disseminated by the traffic management center through roadside infrastructure ***(i.e.*** beacons), via broadcast media, or by other means. The backbone of ATIS is a series of distributed data bases residing on a variety of metropolitan area networks (MANs), wide area networks (WANs) and local area networks that are interconnected. Interconnections and communication protocols are likely to conform with an IVHS open system reference model.

B. Organization of Report

This report is organized as follows. The remainder of tbis chapter sets out the institutional setting in which IVHS deployment will take place. Chapter II discusses key dichotomies that reflect tension, conflict or paradoxical circumstances that underlie many institutional barriers. Chapter III examines institutional barriers from the perspective of different sources of factionalism that can impede deployment. These sources of factionalism are work culture, turf and organizational fragmentation, multiple jurisdictions, and the government hierarchy. Chapter IV recognizes that institutional barriers vary with the phase of deployment, and therefore provides an overview of which impediments to deployment might exist during research and development, testing and design, manufacturing, construction and operation, and finally maintenance, Chapter V examines other issues that have been identified in the IVHS literature, interviews conducted by the Urban Institute, and in the docket containing comments for the report to Congress on the non-technical constraints to deployment of IVHS.

C. The Institutional Setting

Understanding the institutional setting in which ATMS/ATIS will be deployed is crucial to understanding many of the non-technical problems that might impede deployment. The institutional setting has an international and domestic dimension. Related developments overseas, particularly in Japan, Europe, and even Canada and Australia, influence planning, design and deployment decisions in the United States. In this country there are three principal institutional sectors consisting of the private, the public, and the academic sectors. The private sector includes vehicle manufacturers, aftermarket equipment manufacturers, telecommunications companies, developers of digital maps, electronic firms making microprocessors, information service companies, engineering firms, and construction contractors. The public sector includes federal, state, regional, and local governments as well as bridge, tunnel and turnpike authorities. The

academic sector includes universities, colleges, and public and private vocational schools. In addition, there are important institutions that do not fit neatly in-any of these categories, such as the defense sector, IVHS America, professional organizations like the Institute of Transportation Engineers that are not aligned with either the public or private sector and standard setting organizations such as American National Standards Institute and the International Standards Organization. The last, and most important institutional group are IVHS users, including motorists, truckers, transit patrons, shippers and receivers, and public safety officials.

1. International Setting

IVHS has become an international phenomenon. The European DRIVE and PROMETHEUS programs and the Japanese AMTICS program, along with Canadian, Australian and other IVHS programs, pose major policy and coordination issues for the United States. The European Road Transport Telematics Implementation Organization (ERTICO), the cooperative society created in 1992 by the European Commission and headquartered in Brussels, Belgium, has the responsibility for coordinating the implementation of advanced transport telecommunications, performing strategic management for the DRIVE II program, evaluating key pilot projects, supporting urban and inter-urban networks, and developing common standards and functions regarding automatic debiting systems, vehicle location referencing system, and travel data dictionaries.

The complement to the DRIVE program is PROMETHEUS, which is a joint effort by the European automobile industry to improve transportation in Europe. Industrial partners have joined together in a pre-competitive environment to establish through Common European Demonstrations (CEDs) the feasibility of IVHS concepts in five areas: sensors and processing, actuation and vehicle operation, in-vehicle architecture, driver-vehicle interaction, and safety and dependability. PROMETHEUS is clearly a kind of industrial cooperation not inhibited by anti-trust laws. Once partners establish a feasible concept, the partners will turn competitors for implementation. ERTICO will orchestrate the broader application of concepts proved to be feasible through PROMETHEUS.'

The Japanese IVHS program has been largely funded through private industry and was launched with the RACS and AMTICS projects. However, the Japanese are moving toward a stronger public role to assure the proper integration between vehicles and infrastructure. Currently the most prominent portion of IVHS is a series of concurrent projects supported by five government agencies, the Ministry of Post and Telecommunication, the National Police Agency, the Ministry of Construction and the Ministry of International Trade and Industries. These projects are the Vehicle Information and Communication System (VICS), the Advanced Road Transportation System (ARTS), the Advanced Safety Vehicle (ASV), and the Super Smart Vehicle System (SSVS).[2]

2. Domestic Setting

Thirty years ago, many of the principal IVHS players in the private sector were either monopolists or oligopolists. AT&T was a regulated monopoly that was virtually the sole source of long distance telephone service. Local telephone service providers also tended to be regulated monopolists. The automobile industry was mainly comprised of the big three manufacturers: General Motors, Ford, and Chrysler. With the fervor to deregulate that began in the 1970's and

the ascendancy of the European and Japanese automakers, government relaxed the protection of regulation, increased anti-trust enforcement in some respects, and fostered competition. The AT&T divestiture took place spawning Sprint, MCI, and the Baby Bells. The new players on the block became information service companies as much as telephone utilities. Meanwhile Volkswagen, Toyota, Honda and other foreign-made automobiles grabbed significant market share. Today, most of the private sector engaged in deploying IVHS is highly competitive. There are some exceptions, however. Many newer telecommunications services such as cable TV and cellular telephone have been allowed to flourish through franchised monopolies or duopolies. Even though there may be only a single service provider today in some markets, the convergence of communication and computer technology and the globalization of trade has posed competitive threats to virtually every type of company in nearly all IVHS-related markets.

The public sector is comprised of federal, state, regional and local government, plus transportation authorities. The federal government has many agencies with a vested interest in IVHS. These include, among others:

- Congress
- White House
- Department of Transportation agencies, including
  - Federal Highway Administration
  - Federal Transit Administration
  - National Highway Traffic Safety Administration
- Environmental Protection Agency
  - enforces the Clean Air Act
- Department of Energy
  - responsible for energy conservation
  - manages many national laboratories
- Department of Commerce
  - promotes U.S. industrial policy
  - lead agency for proposed national information superhighway
  - responsible for proposed manufacturing extension centers
- Department of Defense
  - determines policy regarding Global Positioning System
  - helps manage partial conversion of defense sector to civilian work
- U.S. Geological Survey

- Bureau of the Census

- National Institute of Standards and Technology.

The states represent 50 different constituencies whose concerns vary with their own institutions, history, geography, urban form, rural settings, climate, and population characteristics. Organizations representing the states include:

- American Association of State Highway Officials (AASHTO)
- National Governors' Association
- Council of State Governments.

AASHTO in particular seeks to develop common transportation policy, and to foster joint action to the extent practical, but rarely do the interests of all of the states coincide.

Regional agencies comprise the next level of government. These include:

- Metropolitan Planning Organizations (MPOs)
- Regional Planning Councils (RPCs)
- Councils of Governments (COGs).

The MPOs, one for each urban area having a population of 50,000 or greater, are designated by the governor of each state to carry out the "3C" planning process begun in the 1970s. The larger MPOs, in urban areas having populations of 200,000 or greater, must comply with specific provisions of ISTEA, including:

- developing transportation programs consistent with realistic financial plans

- helping assure compliance with air quality standards in non-attainment areas

- implementing a metropolitan planning process

- establishing six specific management systems in cooperation with the state.

Some regions have more than one MPO. RPCs and COGs are common but not universal; where they do exist their responsibilities are related to and sometimes overlap the responsibilities of the MPOs. The National Association of Regional Councils represents and helps to coordinate the MPOs, RPCs, and COGs.

In the United States there are nearly 3000 counties and approximately 19,000 municipalities. In any region, there can be several counties and a large number of municipalities. The National Association of Counties represents the counties' interests, and their affiliate, the National Association of County Engineers, represents the interests of county engineers. The National Urban League and the U.S. Council of Mayors look after the interests of the cities.

Besides these institutions, states often grant charters and similar legal authority to agencies that establish and manage toll roads for turnpikes, tunnels and bridges. Achieving cooperation and

coordination among agencies responsible for toll roads and free roads is alone a major institutional challenge.

Users are also well represented. The interests of motorists, the largest potential market for IVHS, are promoted by organizations such as:

- American Automobile Association
- Highway Users Federation
- traffic safety consumer groups.

Transit and para-transit users, a much smaller but important constituency, are represented by organizations such as:

- American Public Transportation Association
- American Bus Association
- Airport Ground Transportation Association.

Users of specialized transportation also have industry associations to address their concerns; an example is the International Taxicab and Livery Association.

Environmental groups are an important constituency that will ultimately have a real impact on the final form of IVHS. These groups include:

- Surface Transportation Policy Project
- Rails-to-Trails
- Sierra Club
- Environmental Defense Fund.

These groups are respected by the public, are vocal and persistent, and are well represented in Washington. They were consulted before the reauthorization of the surface transportation program in 1991, and influenced key provisions, especially those related to the Clean Air Act. They will no doubt stay engaged with an issue as important and far reaching as IVHS, and should not be discounted in the future as IVHS program managers seek approval for deployment.

Finally, there is IVHS America. IVHS America is a 501(c)(3) educational and scientific, private, non-profit organization, chartered as a Federal advisory committee to the U.S. Department of Transportation on IVHS matters. Its membership includes private organizations, universities, associations, federal, state and local government agencies, and other public organizations. It seeks to develop a consensus among its members regarding research, development, and implementation of the federal government's IVHS activities.

IVHS America has developed a strategic plan for the IVHS community, private and public, to guide the transition to full implementation over the next 20 years. The strategic plan is intended to cover the full scope of the IVHS program, including:

- national objectives
- identification of problem areas
- specification of necessary research

- establishment of the roles of public, private and academic participants
- preparation of a plan of action
- identification of system architecture(s) and standards.

The strategic plan's ultimate goal is the creation by the private sector and the government of the advanced transport products and services that will materialize as the 20th century yields to the 21st.

The Policymaking bodies of IVHS America are the Executive Committee and the Coordinating Council, which are supported by an executive director and staff and a series of technical and subcommittees. These committees, which will play a critical role in sorting through key issues and developing policy options, are responsible for the following topics:

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)
- Automated Vehicle Control Systems (AVCS)
- Commercial Vehicle Operations (CVO)
- Advanced Public Transportation Systems (APTS)
- Advanced Rural Transportation Systems (ARTS)
- Strategic Planning
- System Architecture
- Safety and Human Factors
- Standards and Protocols
- Institutional Issues
- Legal Issues
- Benefits, Evaluation, and Cost
- International Liaison
- Clearinghouse and Editorial Review
- Environment and Energy.

II. CHAPTER TWO -DICHOTOMIES UNDERLYING INSTITUTIONAL BARRIERS

Many potential barriers to deployment arise from a conflict or tension between constituencies or approaches. In this chapter we describe the conflict or tension in terms of the underlying dichotomies that give rise to institutional barriers. Some dichotomies (e.g., "public vs. private", "Federal vs. local") are widely recognized; others (e.g., "prices vs. shadow prices", "control vs. information") are more subtle but no less instructive.

A. Public Versus Private

Because the public sector has responsibility for traffic regulation and management on public roads including operation of traffic signals, the private sector cannot unilaterally deploy ATMS. It can become involved in the deployment of ATMS only in partnership with or at the behest of the public sector. The public sector, through its power of eminent domain and other legal and regulatory powers, can also acquire rights-of-way for laying conduit, a power which the private sector lacks, and can confer it on the private sector through franchise and other licensing agreements. The public sector currently relies on equipment and communication technology which the private sector provides, and is ill-suited to manufacturing, construction, installation, and providing many kinds of technical services needed for ATMS. The public sector, if it chooses to, can exclude the private sector from directly participating in certain phases of deployment of IVHS, (e.g., design, operations, and maintenance), provided the public sector acquires or nurtures the needed skills. It is unlikely to exclude the private sector from construction and installation. A metropolitan region excluding the private sector from certain phases of deployment incurs risks which could affect the short and long run success of implementation. If the public sector designs a traffic management center for example, and lets a contract for its construction in the same manner as a road building project, as it has in Fort Worth, Texas, it may facilitate deployment because the agency can avoid having to develop a different procurement process. On the other hand, the agency would forgo expertise the private sector offers. The public sector could also assume the responsibility for operations and maintenance, but experience with existing urban traffic signal systems suggests that inadequate staff and financial resources have impaired their functioning. Some of the capabilities of newer systems remain unused or often fall into disrepair, which does not bode well for ATMS. Here the private sector has two advantages:

- A private sector firm can decline to accept a project that does not promise to be profitable; and
- The private sector, with its profit incentive, is more likely to maintain its investments if it has long term responsibility.

A public agency, in contrast, must implement a project if required to do so by the relevant governing body. Having committed to the project, the agency may later be denied the funds required for proper maintenance and operations.

The public sector is also likely to be the source of real time traffic data for ATIS, which would be collected through the ATMS and would be disseminated for free or at some cost. The private sector is expected to bundle other data and information services with the traffic data and sell it, although there is no inherent reason why the public sector could not potentially do this as well. In implementing ATIS, the private sector could, if it develops its own traffic surveillance

data based on probes or remote sensing, circumvent any reliance on publicly provided traffic data collected through an ATMS.

In sum, the public sector is more likely to deploy ATMS, but will not necessarily do so, and the private sector is most likely to deploy ATIS.

B. Chickens Versus Eggs

While both the private and public sectors have agreed to share the costs of much R&D and operational tests, each is highly dependent upon the other for widespread implementation of IVHS. The public sector cannot realize the public benefits of IVHS without a full commitment from automobile and other equipment manufacturers to mass produce and install in-vehicle navigation and routing equipment and develop related databases. The private sector cannot fully realize its profit opportunities without accurate, reliable, real time traffic data delivered to vehicles, currently viewed as a public sector responsibility. Thus to some degree the private sector is sitting on its hands waiting for the public sector to build traffic management centers and surveillance systems, to implement real time traffic control systems, and to provide traffic data for dynamic route guidance. At the same time the public sector sits on its hands waiting for the private sector to commit to mass production of in-vehicle navigation and routing aids and to develop data bases for ATIS. As long as the public sector does not do its part, broad-based horizontal markets will not develop. In this case the private sector will deploy ATIS products mainly in vertical after-markets and take advantage of short-run profit opportunities, which some characterize as profit skimming.

There are other chicken-and-egg problems that affect IVHS deployment. One is that a cohesive national (or even international) system depends upon the development of a national system architecture. However, development of a sensible and successful one cannot proceed without the benefit of input from operational tests and other early implementation experience. But early implementation would be best served if guided by a national system architecture. The reality is that implementation in many regions will outstrip R&D, operational testing, and the effort to develop a national system architecture. Significant nationwide implementation is likely to occur before a nationwide framework is established Regions that have made large investments in operational tests will be very reluctant to modify their systems to conform to a national system architecture, unless the architecture concept is extremely flexible and open enough to require little adjustment. This is not to say that systems of early implementers will not undergo upgrades and evolution. They certainly will, and the early implementers will have reaped early benefits, but the benefits would not be as large as if the regional systems were to conform to a national system.

Another chicken-and-egg problem is as follows. Large numbers of government agencies are unwilling to become involved in IVHS unless they can be convinced that the benefits of IVHS warrant their involvement and that there is sufficient funding for staff, operations and maintenance as well as for initial implementation. However, the funding for operations and maintenance through federal and state sources is unlikely to be forthcoming without the commitment to IVHS and political support of local and regional officials. The political support is unlikely to be forthcoming unless local and regional officials are convinced of the benefits of IVHS; further, the benefits, which can be estimated in advance through models and calculations, will only become known through operational tests and implementation experience involving local and regional governments.

Politicians at the national level will be unwilling to finance the deployment of IVHS unless there is some matching local commitment. Evidence of local commitment can take a number of forms including in-kind services in R&D, operational testing, planning and design, and helping to fund construction, installation, operation and maintenance. But it is unclear whether many local governments can or are willing to make this commitment without strong evidence of federal and state support.

None of these chicken-and-egg problems is so damaging as to preclude the deployment of ATMS and ATIS, but singly or in combination they can greatly slow the deployment and prevent the public and private benefits from being fully realized.

C. Top-down Versus Bottom-up

There exists a major dynamic tension between national and local officials as to whether IVHS should be implemented from the top down versus from the bottom up. A top-down approach is seen as resulting from a national level implementation in contrast to the bottom-up approach being the result of local and regional initiatives. National level planning will permit vehicles operating anywhere in the United States, and even abroad, to reap the benefits of a local ATMS/ATIS that conforms to national or international standards. Local planning and design is more likely to be responsive to the unique characteristics of the region where IVHS will be implemented. Either approach pursued exclusively is fraught with danger. The IVHS community is clearly cognizant of this danger, and top-down efforts are being pursued in parallel with bottom-up, so they benefit from one another. The consensus building element of national system architecture project, and the outreach efforts of IVHS America are but two ways for nationally based activities to reach down to the local/regional level. Results of operational tests will feed the national level effort.

D. Federal Versus State and Local Roles

There has been a tension between federal and state government since the early days of the Republic. Over time the tension has extended to the local level of government as well. The formalized division of powers defined in the Constitution codified a compromise, circa 1787, but court decisions and Congressional actions in subsequent years have made changes in federal and state roles. These changes, though occurring at the margin, were not insignificant.

From the New Deal through the Great Society, the federal government centralized both decisionmaking and fiscal power. In addition to the greatly expanded role of inherently federal programs (e.g. defense), the federal government centralized regulatory powers to moderate the centralization and concentration of big business. The federal government also undertook important social programs on a national scale such as establishing Social Security to provide retirement benefits.[3]

In the Nixon years, the federal government decentralized control of spending, giving lower level governments and individuals more decisionmaking power over the purposes and design of social programs. Revenue sharing, block grants and the negative income tax for families augmented and in some instances replaced more restrictive categorical grants. Behind these particular instruments lay a democratic principle: that the constituents who finance and benefit from the programs should also have the responsibility and opportunity to participate in the

conception and implementation of the programs. Today we might call this "empowerment" and "participatory democracy." .

In the Reagan/Bush era, conservatives sought to decentralize the funding of social programs in an effort to decrease the level of funding. They sought also to replace cooperative federalism with competitive federalism[4] so that states and local governments, competing for the favor of businesses, would have to lower taxes and social spending.

As federalism evolves, the federal government takes on increasing responsibility for equity issues, while states and local governments are gaining responsibilities over efficiency issues. Most of the entitlement programs are funded at the federal level, probably stemming from the conviction that the interests of a weak constituency (poor people) are best provided for at the highest level, furthest removed from local prejudices and parochialism. In addition to its role as equalizer for individuals, the federal government is in the best position to redistribute resources from rich to poor regions of the country.

Of course state and local governments also redistribute income and offer social programs, but their comparative advantage lies in the area of efficiency. State and local officials have a better understanding of regional or local market dynamics than their federal counterparts. Consequently, they can more effectively design a public goods project like IVHS than their federal counterparts.

The above (mercifully short) review of the evolution of federalism serves as part of the backdrop for the interjurisdictional tensions seen in the planning for IVHS. By viewing these tensions in the broader context one can more easily appreciate the problems and design effective solutions.

Based on the efficiency advantage, perhaps the federal government should avoid mandating a single design for IVHS. By promoting an open system architecture, establishing national standards and protocols, offering block grants or other discretionary subsidies that would enable lower level governments to tailor IVHS to the idiosyncracies of their metropolitan housing and jobs markets, a more efficient outcome may result.

E. Centralization Versus Decentralization

A contentious issue within the IVHS community is the extent to which ATMS should be centralized or decentralized. The fact that a traffic control center would be an integral part of an ATMS causes many people to conclude that ATMS will necessarily be controlled centrally. It would seem that if an ATMS were to have capabilities of traffic surveillance, real time management of signals, ramp meters, changeable message signs, and responsibility for deployment of incident management teams, that all of these would be under the control of single authority often housed in a single facility. There are, however, many reasons for decentralizing ATMS. These include:

- local jurisdictions enjoy home rule and desire local control,
- traffic signal controllers are used to manage signals locally even if they are also part of larger traffic control system,

- information and data on route choice might best be provided by telecommunications in the immediate vicinity of each vehicle,

- traffic advisories displayed on changeable message signs are local, and the implicit prices (travel time costs) of route choice are experienced as local prices (see the discussion below concerning prices and shadow prices).

Institutional planning for IVHS can benefit from contemplating the advantages and disadvantages of centralized versus decentralized economies. It is important to realize that trip making is a market and subject to the same economic frailties as any other market. The experience of communism in trying to impose centralized control on systems that would otherwise function as decentralized markets is an extreme example of the inefficiencies that sometimes result from overcentralization. Indeed a traffic management center will have trappings that will allow it to exert central control over traffic flow, but if not done properly it could diminish the effectiveness of IVHS or even backfire. Exerting centralized control "properly" might mean fostering decentralized control or centrally controlling traffic "as if' all decision were decentralized.

To give an example of poorly managed centralized information dissemination, one of the authors had the following experience traveling on I-95 between Washington, D.C. and New York City. Upon approaching the Baltimore Harbor Tunnel, a changeable message sign warned of congestion ahead. About twenty miles further north traffic jammed up and slowed to a crawl for approximately three miles. Congestion suddenly let up as soon as traffic reached a sign by the road which said roughly speaking, "Traffic Alert, for Information Tune Radio to 530 AM." Large numbers of drivers, including the author, upon seeing the sign, leaned down, switched the radio from FM to AM, tuned the dial to 530, listened to a radio transmission full of static, and were barely able to hear a pre-recorded message saying that the states in the I-95 corridor were coordinating to relieve traffic congestion and would provide highway advisories if road conditions warranted it. What appeared to be happening is that large numbers of people were slowing down at the "Traffic Alert" sign as they tried to tune in to a message that contained no useful traffic information. The result was that the highway advisory radio which was intended to provide information to inform motorists and relieve congestion, was in fact the cause of a three-mile backup.

F. Prices Versus Shadow Prices

Prices serve to allocate scarce goods or services among various consumers, and if prices depart significantly from socially desirable levels, the outcome is inefficient. It is widely recognized that the price people pay for highway travel in terms of out-of-pocket costs is not a socially efficient price. Excessively low out-of-pocket costs is an inducement for large number of drivers to use the automobile and select already crowded routes rather than other modes and less crowded routes. Out-of-pocket costs are so low that travel time is the implicit price that allocates scarce highway capacity among users. In a capitalistic society that prides itself on reliance upon markets that are as efficient as possible, we use the same method to allocate highway capacity among road users as the former Soviet Union used to ration bread to among the Soviet people: waiting in lines. [No one starved in the Soviet Union, and no one fails ultimately to arrive at his or her destination in the United States, but this method of allocation of resources is no more efficient here than it was there.] Out-of-pocket costs is the dollar price but travel time is a type of shadow price that currently governs mode and route choice decisions even more. It is worth

noting that modelers often explain and predict mode and route choice based upon a composite price of various types of out-of-pocket costs (gas, parking, bus fare) and travel time costs (time in transit, wait time, transfer time), and that people value different types of travel time differently.

The emergence of telecommuting raises additional practical problems for designers of ATIS. Travel time, is no longer the determinant of mode choice; instead various attributes of working at home and working away from home, including specific dimensions of personal accessibility are the determinants instead. The ability to reach co-workers at will by fax, telephone, and video needs to be factored in.

Some of the institutional impediments to implementing elements of ATMS arise because of the wedge that exists between the price people pay to use the roads (and other modes including telecommuting) and the way they value their choices. For ATMS and ATIS to be implemented most effectively, designers must be very careful regarding the relative prices of travel options communicated to the traveler. If designers of IVHS are confused about how people place values on transportation mode and route choice and communicate signals for allocating scarce highway capacity inconsistent with how people value travel choices, the entire ATMS/ATIS system will suffer and could be partly discredited in the public eyes.

G. Control Versus Information

ATMS and ATIS will produce a huge quantity of information that must be distilled for use by the traveler. Providing information in the optimal amount and time is key to effective implementation. Information a driver needs en route is much different than information a traveler needs before starting a trip. A driver can absorb only so much information without being distracted and impairing safety. In-vehicle computers and displays, coupled with telecommunications, will serve multiple purposes of route planning and real-time navigation and routing based on current traffic conditions. There are important tradeoffs in determining what information should be provided to induce individuals to make decisions that optimize traffic performance over the network, and thus bring individuals acting autonomously under network-level control. Individuals need to be given only that information essential for making choices en route that either enhance driving performance or produce system-level benefits of reduced congestion, accidents, pollution and so on. Providing additional information en route such as attributes of origins and destination, may diminish the effectiveness of ATIS/ATIS. Moreover, telecommunication bandwidth available for ATIS applications and costs may require data communication by exception, as opposed to furnishing large quantities of data that must be digested by either the computer, the driver or both.

Tradeoffs in managing the quantity and timing of information for purposes of control are less evident for ATIS used in pre-trip planning. Decisionmaking is much more leisurely prior to undertaking a trip, and the traveler and system-level benefits are more likely to maximized if the traveler can have access to as much useful information as possible concerning attributes of destinations, modes, and routes. In the future, travelers will probably be able to access large numbers of data bases through network interconnections, and will thus be able to make better travel choices prior to departing.

H. System Versus Individual Benefits

IVHS is vulnerable to the fallacy of composition: system level performance and benefits do not necessarily follow from individual performance and benefits. A classic problem in IVHS is that individuals seeking to avoid congestion by relying on real-time information concerning travel time on alternative routes, will shift in mass to the alternative route and create more congestion.

There is an analogous problem in designing route guidance algorithms for in-vehicle routing equipment used in ATIS. Algorithms can either advise individuals to take routes based on the minimum travel time for the individual, or the routes that minimize system-wide congestion and delay. If ATIS recommends routings based on system-level criteria, and drivers can discern the difference in the travel time on the recommended route versus the route they know requires the least time, they will come to question the recommendations. This could undermine public confidence of dynamic route guidance, with potentially serious repercussions for widespread public acceptance.

If dynamic route guidance systems are designed to offer routings based upon minimizing travel time for each individual, system benefits could be significantly diminished in comparison to maximizing system-level benefits of travel time savings. Worse, if providing route guidance information that minimizes individual travel time results in herds of vehicles choking alternative routes, it could easily galvanize political opposition to IVHS.

Traffic engineers and operations research specialists currently developing routing algorithms for ATIS are aware of these problems and are trying to minimize them.

I. Internal Versus External Benefits and Costs

Many potential institutional barriers arise because of externalities. When people experience costs that have been imposed by others, or reap benefits for which others have borne the costs, it creates social and political discord. There are two types of externalities, production and consumption. Production externalities occur when a producer of a good or service imposes costs on others in excess of the costs of production or produces benefits that do not accrue to the producer. An example of an external cost is air pollution for which the producer does not pay any air pollution costs. An example of an external benefit is a community that undertakes an investment whose benefits spill over into other communities which, to use the economist's term, become "free riders." Consumption externalities occur when consumption by one person of a good or service positively or negatively affects the consumption by others. Congestion is a classic example of a consumption externality. A decision by a driver to enter a roadway, imposes some incremental reduction in travel time upon all the other vehicles in the traffic stream.

The solution to the problem of externalities is to internalize the costs and benefits. For example, congestion pricing might be used to force drivers to face the marginal costs they impose on others in a traffic stream. Similarly, an agency undertaking operational improvements to roads, from which noise or air pollution emanates, should incur the costs of any increase in noise and air pollution. To solve the "free rider" problem of external benefits, whether in terms of reduced congestion, pollution, and so on, all recipients of the benefits should share in the costs.

ATMS/ATIS is potentially vulnerable to the "free rider" problem in a metropolitanregion. One or several communities may refuse to participate in a regional ATMS/ATIS, but its residents would benefit from a regional system that excludes them. This could provoke resentment among the others who have agreed to share the costs of implementation. The holdouts could generate such resentment that it completely erodes the support among those who originally agreed to implement the ATMS/ATIS.

Environmental side effects resulting from ATMS and ATIS are also a potentially worrisome impediment to implementation. The burden is upon proponents of IVHS to demonstrate that specific elements of IVHS implemented in a region, such as ATMS and ATIS, will not adversely affect the environment, and if negative environmental side effects do occur, that appropriate steps are taken to internalize and/or mitigate the costs. Many environmental groups are fearful that IVHS will significantly improve accessibility and induce traffic causing additional air pollution ***(see Chapter*** V.F.2.) They would be more sanguine about IVHS if the implicit price (i.e., a composite of travel time and out-of-pocket costs) more closely reflected the true marginal social costs of driving. Many environmentally concerned people favor significantly increasing gas taxes or imposing congestion pricing. Absent an increase of costs imposed on drivers, implementation of ATMS and ATIS may have to overcome significant pockets of opposition from advocates of environmental protection.

J. Users and Non-Users

A distinction related to externalities is that between users and non-users. The costs and benefits of ATMS and ATIS will be distributed among users and non-users in ways that can also breed social and political discord. Users will tend to be automobile users and shippers, though the IVHS community is striving to ensure IVHS addresses other modes of transportation, especially transit. If the IVHS community fails to encompass non-auto and non-truck users in a meaningful way, there could be vociferous complaints of inequity and charges that an already un-level playing field that favors highway transportation is being tilted even further in favor of highway transportation. This flies in the face of the thrust of ISTEA which emphasizes multimodal and intermodal solutions to transportation problems. The IVHS community certainly has recognized the importance of mass transit by establishing Advanced Public Transportation Systems to call attention to transit applications. However, the IVHS community has yet to realize it is equally vulnerable to political action from the rail, air, waterborne, and pipeline freight sectors. And it should not underestimate strong feelings among those who feel bicycle and pedestrian transport is being slighted.

K. Affluent Versus the Poor

If congestion pricing were introduced along with electronic toll collection, the costs of using congested facilities during peak hours could be brought more in line with the economically efficient price. Politicians and the public, however, have shown a great distaste for congestion pricing because they see it as inequitable, imposing disproportionate costs on the poor. Integration of electronic toll collection with ATMS may be difficult if politicians and the public see it as first step toward congestion pricing rather than a means to alleviate congestion at toll plazas. If electronic toll collection were ever perceived as so integral to ATMS as to permit congestion pricing, ATMS might prove politically infeasible.

L. Mandatory Versus Voluntary

There is dynamic tension among those in the IVHS community who feel certain elements of IVHS should be mandatory and others who feel all elements should be voluntary. Volunteerism is appealing to those who believe that a national IVHS system should emerge through consensus and conviction on the part of participants that the benefits of M-IS exceed the costs. To many, the heavy hand of the federal government is abhorrent.

One of the main problems with volunteerism is that IVHS may fall far short of realizing the maximum possible private and public benefits. Unless the federal government induces or mandates all public and private suppliers and users to participate in IVHS, the program may fail to live up to its promise.

Mandatory elements might include national requirements for compliance with safety and other standards. The federal government might mandate that automobile manufacturers include a transponder in all vehicles to identify vehicles and enhance the efficacy of IVHS. The federal government might even mandate participation of localities in a regional ATMS/ATIS, to ensure the benefits of regional systems are maximized, and ensure compatibility of regional IVHS systems throughout the country. The Interstate Commerce clause of the Constitution gives the federal government the power to impose these requirements.

The government must be exceedingly circumspect and proceed very gingerly in implementing any mandates, otherwise a backlash could result. Fortunately the effort to establish a national system architecture and other related activities are sensitive to the effect mandates would have. Safety standards and mandates for IVHS equipment will meet stiff resistance. Other standards for equipment and telecommunications are likely to suffer strong objections of businesses whose interests would be harmed. Installing transponders in vehicles raises the specter of "Big Brother." Forcing localities or regions to participate in a national system or a regional system would result in strong protests.

M. Carrots Versus Sticks

A mandated system is too heavy-handed and volunteerism is too light. The most likely way that the federal government will attempt to achieve national goals for IVHS is through a combination of "carrots and sticks." Indeed, this approach is already strongly evident in the operational tests and the R&D program underway. The federal government is providing funds to leverage financial resources of private firms and state, regional and local agencies. Research and development contract awards and grants to universities and transportation research centers are also providing inducements to regional and local agencies to become involved in IVHS. The emphasis that the federal government places on carrots versus sticks, will affect the speed of deployment of ATMS/ATIS and the willingness of various entities to participate. On balance, carrots are preferable to sticks.

N. Exceptions Versus General Rules

A key question is whether deployment and operation of IVHS should be managed by exception or by general rules. In other words, should policies and procedures be developed that apply universally, allowing no variation among specific circumstances, or should one permit

considerable variation and attempt to manage only that which crucially matters or which is a problem? This question is an important variant on the issue of how appropriate mandates are, and applies both to institutional and some important technical elements, especially telecommunications. Managing by general rules has the virtue of completeness but the liability of higher costs. Successful deployment could fall victim to a management approach which over-emphasizes either one.

From a technical standpoint it is too costly to transmit all the data a driver might ideally want Because of spectrum allocation and handwidth constraints, data transmission costs can be minimized by communicating only information that is changing or is an exception to the background information.

O. Vehicles Versus the Infrastructure

To what extent does IVHS equipment belong in vehicles or in the roadside and telecommunications infrastructure? There are many technical and non-technical tradeoffs in answering this question. An important institutional issue is the degree that the private and public sector will bear the costs of deployment. The more ATMS/ATIS relies on in-vehicle equipment, the higher the added costs to automobile manufacturers. These extra costs will tend to depress overall sales of vehicles on the one hand, because vehicle sales decline as auto price increases. On the other hand, drivers may be willing to pay a price substantially in excess of costs because of the value added by the IVHS equipment, and this may represent a profit opportunity that more than offsets the decline in profit from automobile sales. If auto manufacturers cannot achieve economies of scale in production of ATIS equipment, they will not risk lower sales owing to increases in auto costs, and will leave manufacturing and installation of in-vehicle navigation and routing aids to aftermarket suppliers.

While the private sector would like to shift as much as possible of the IVHS cost to the public sector, the public sector (and the taxpayers) would probably prefer the reverse.

P. Equipment Versus Communications

Who owns the equipment in contrast to the telecommunications infrastructure has important institutional ramifications. In addition, major institutional realignments may occur depending upon whether the locus of "intelligence" required for IVHS resides in equipment or the telecommunications infrastructure. Various private and public entities will seek to retain ownership and control over those components they currently own or control. Thus public agencies will desire to retain responsibility for the roads and roadside, vehicle manufacturers will want to maintain their influence over the equipment installed in vehicles, and telecommunications companies will desire to maintain their hold on the telecommunication media. Maintaining these separate domains will prove to be increasingly elusive as computer and telecommunication technology converge and microprocessors can be placed virtually anywhere in the system at very low cost. Telecommunications suppliers will seek to shift the intelligence needed for IVHS from the equipment and roadside infrastructure to the telecommunications network. Automobile manufacturers and the public sector may or may not go along. If they do not go along, either the market will resolve the issue or there will be a public policy battle. A heated and protracted public policy battle could delay the deployment of IVHS.

Q. Wire Versus Wireless Communications

Much of the earlier thinking regarding the deployment of IVHS, especially by those not involved in the vanguard of the telecommunication industry, assumed that wire technology (optical fiber, coaxial cable, and even twisted pair coupled with data compression techniques) would serve as the telecommunications medium for ATMS, because in-ground wire systems are the backbone of current urban arterial traffic signal systems. Broad band optical fiber systems can handle large amounts of data processed by video cameras, loop detectors, and other sensors. In addition, optical fiber networks have been proliferating and expanding in urban areas. Telecommunications companies, cable television operators, public utilities, transportation agencies and others have laid conduit containing optical fiber cable. Transportation agencies pursuing IVHS can either lay additional cable to meet the needs of ATMS or establish interties with other networks to meet their needs.

Cellular broadband wireless communication technology has emerged more recently. There is a good chance that microcellular networks will be constructed in many urban areas before the end of the century. Global satellite systems such as Motorola's Iridium project are perhaps the most venturesome new technology. The personal digital assistants (PDAs) that have recently emerged point the way to a whole new generation of portable smart communicating terminals. Paging and cellular technology have existed for some time, and a large percentage of the public has come to rely on these systems. The concept of ATIS includes providing real-time travel information not only to people at home and at work, but also to people on the move under all types of circumstances--in vehicles, waiting at bus stops, and walking around.

When the wireless telecommunications infrastructure becomes widely deployed, its costs could become highly competitive with the costs of systems based on optical fiber, and regions deploying ATMS/ATIS might find wireless technology relatively attractive. If this were to occur, it would loosen the public sector's grip on ATMS, and would have significant institutional ramifications for the way ATMS is deployed: the private sector would probably be more involved and the public sector less involved.

The development of wireless technologies is not likely to result in any barriers to IVHS deployment. Quite the contrary: it is likely to speed its deployment, extend its reach, and enhance the quality of its information services. In the worst case, firms jockeying for short term market position will create a contentious and confusing environment for IVHS planning and policy making.

R. Regulation Versus Laissez Faire

The fundamental choice in any market is between competition and monopoly. Monopoly is the opposite of a competitive market; regulation is the attempt of government to protect the public from exploitation by a monopolist, or to gain some of the advantages of a free market in the presence of monopoly. Regulation is in a sense the price exacted by government in exchange for toleration of monopoly.

In principle, any market can be regulated or free; the U.S. economy is replete with examples of both approaches. Each has its own unique advantages: regulated markets tend to be orderly and static, yielding predictable supply and stable prices, while free markets tend to be

more unpredictable and volatile in both supply and price. Each is efficient in its own way, regulated markets by exploiting economies of scale or limited resources and free markets by exploiting innovation and flexibility.

In a capitalist economy such as the United States, free markets are the rule and regulated markets are the exception. We tend to embrace regulation for a particular market only if competition proves unworkable. Monopoly (and thus regulation) is appropriate if true economies of scale yield substantially lower costs; if sufficient quantities of a necessary natural resource (e.g., the radio spectrum) are unavailable to allow multiple users; if undue disruption of public life would result from free competition, such as digging up streets or planting telephone poles; ***etc.***

Although government often imposes regulation to protect the public from the unbridled exploitation of a monopoly, private sector entities sometimes seek regulation to protect their markets or their investment or to limit their risk. In many such cases, the interests of the public and private sectors differ greatly; each seeks regulation for its own purposes, but those purposes are inherently contradictory. The regulated firm seeks a protected market, low risk, and a high profit or rate of return, while the public sector seeks for itself the benefits of any underlying economies of scale, low and stable prices, and reliable, high quality service. Thus the public sector uses regulation to gain for itself the benefits of competition in the presence of monopoly, while the private sector uses regulation to gain for itself the benefits of competition in the absence of risk.

Markets tend to develop slowly, and regulation tends to be considered by government only when (a) firms are unwilling, due to risk and uncertainty, to supply a product or service provided highly valued by the public, and (b) existing vendors so dominate the market that such new entrants are unduly frustrated in their attempts to gain a foothold. The monopoly supplier of buggy whips need have little fear of regulation, while the Congress itself recently limited cable television operators to less than a 25 percent market share.

What is the relevance to IVHS of the choice of regulation vs. the free market approach? Although government typically imposes regulation only after demand has developed and monopoly power is being exploited by dominant firms, government seeks to "jump start" IVHS. Thus monopoly franchises are being considered seriously by government as a means to reduce the risk of entry and thus to encourage the development of these new services; regulation is in turn the quid ***pro quo*** for monopoly franchise. Further, a market for some IVHS services is unlikely to develop rapidly without external stimulus of both the demand and supply sides (see the discussion of the chicken and egg problem above). By granting monopoly protection, government hopes to reduce the business risk to the private sector.

Experience in other markets suggests that government should proceed with care as it considers the monopoly/regulation option as an alternative to competition. First, the cost in innovation foregone can easily exceed the savings from economies of scale, even if such economies are indisputably present. Second, once granted, franchises are difficult to revoke; even if the bargain initially struck provides for the scheduled demise of its preferential rights, a regulated entity often develops a life of its own, acquiring market and political power great enough to moot a sunset provision or to press a renewal of authority. For example, only the naive among us would expect that the television broadcast stations will ultimately be forced to give up their existing frequencies, as the FCC has provided, in exchange for the HDTV frequencies they will soon receive.

Also, it is difficult to establish a rationale, beyond the recovery of initial risk capital, for monopoly provision of many IVHS services. The technologies are already well known and widely used in other industries and markets. Many of the facilities required (e.g. data bases and transmission facilities) do not exhibit substantial economies of scale or other characteristics consistent with monopoly ownership, and those that may (e.g. loop detectors or surveillance cameras) will probably be publicly owned. Much of the information to be transmitted over these facilities (e.g. traffic congestion data) will be generated by public agencies. Finally, there is little need for central control of the information or services to be provided to motorists, beyond certain limited restrictions that will in any event be applied by public agencies at the source.

Thus monopoly provision of services and facilities are probably applicable only to a limited class of IVHS markets, probably those that are infrastructure related (e.g. instrumented roadways or toll facilities). Most other markets will probably benefit more from the robustness and flexibility that is characteristic of free and unbridled competition.

S. Initial Cost Versus Life Cycle Cost

For virtually every item we purchase, except consumable items such as sandwiches or pencils, there are several components to the relevant cost. In addition to the initial cost, we must consider the costs of operations, maintenance and repair. Also, in a high technology procurement the low bid is not necessarily the best choice. It is difficult to balance price and quality when procurement decisions are based upon the low bid.

In the IVHS community, experienced policymakers are well aware of the tension between on the one hand keeping initial costs as low as possible and on the other hand fully accounting for life cycle costs. The best known example is the lack of funding for maintenance of the Interstate highway system in its early years, leading to substantial deterioration and a resulting need to rebuild large parts of the system at much greater cost. For high technology equipment and systems such as will be required for IVHS, this problem is very much greater-the modes of failure are more complicated and more numerous, obsolescence is an inherent characteristic of such systems, and the costs of repair or replacement are significant.

There are many ways to deal with life cycle cost issues. For policymakers, one way is to pass the problem on to the private sector by negotiating long term contracts or by defining the particular service as a competitive market. If government procurement is unavoidable, careful and persistent attention to life cycle costs at every stage of the procurement is essential; to proceed with capital improvements without a budgetary guarantee of coverage of continuing costs invites serious problems in the future.

Government is a creature of the political process, and the risk/reward ratio for politicians is almost always more favorable for capital expenditures than for maintenance and operations expenses. Moreover, when funds are limited (they always are), this year's capital requirements always seem more urgent than maintenance of last year's capital improvements. It's a constant battle. The only way to limit damage is for an agency to be forthright and diligent internally, and to be unremitting in its effort to publicize the consequences of inattention to maintenance to those outside the agency who are involved in the budgetary process.

III. CHAPTER THREE — FACTIONALISM AS A BARRIER TO DEPLOYMENT

Chapter II focused on dichotomies that reflect important dynamic tensions underlying potential barriers to deployment of ATMS/ATIS. This chapter focuses on sources of factionalism that inhibit cooperation among key players that must work together to deploy ATMS/ATIS. Principal sources of factionalism are work culture, multiple jurisdictions, turf and organizational fragmentation, and the hierarchy of governments.

A. Work Culture

Many of the fundamental splits among the public, private, academic, and defense related sectors, arise in part because of very different work cultures. Those in the private sector tend to be motivated by profit and more inclined to take risks than in other sectors. Within the private sector, however, there are substantial differences among types of firms. The automobile industry, which is poised to be the Original Equipment Manufacturers (OEMs) for ATIS equipment, is accustomed to making incremental changes, requires fairly long lead time to plan instrument panels for mass production, strenuously resists inclusion in the basic vehicle of any features that are not extremely low in costs, and requires economies of scale to warrant mass production. These characteristics of the auto industry helped shape a management work culture that until recently has been conservative and resistant to change. The major U.S. automobile manufacturers were smug in their world wide dominance and inclined to rest on their laurels until foreign competition sent them reeling. The conservatism, a strong legacy of earlier decades of unquestioned supremacy of U.S. car makers is still evident today, not withstanding massive layoffs, adoption of Japanese quality management techniques, and U.S. automakers having become much more nimble and adaptable.

Many of the larger firms in the telecommunication industry, especially AT&T and the Baby Bells, have not fully shaken their legacy of being regulated industries, and also have a conservative streak. However, through both strategy and necessity, they are becoming more and more like many of the new telecommunication companies such as cable TV operators, cellular companies and firms in the fast-paced computer and electronics industries. In many of these industries products become obsolete in six months to a year, and firms exhibit extraordinary flexibility and risk taking. These firms tend to be closer to the customer, cannibalize their own product lines, and reinvent themselves routinely. Stability, job security, and conservatism are not part of the work culture.

A civil and traffic engineering work culture pervades some of the firms that supply equipment (controllers, loop detectors, ramp meters) and software for traffic signal systems and freeway surveillance systems. Their principal market is government transportation agencies. Since government agencies have been slow to innovate, it is not surprising that U.S. firms providing this type of equipment do not evolve as fast as most electronic and computer firms. Nonetheless, firms currently supplying traffic signal and freeway surveillance systems are likely to be major players in the design, deployment, and perhaps even operations and maintenance of ATMS.

The public sector's *raison d'etre,* in contrast to the private sector, is market failure. The public sector tends to rely on regulation to achieve its goals, and is usually risk averse, fearful of its accountability to both the electorate and elected officials. The public sector is also usually (but not necessarily) more bureaucratic than the public sector. At the federal, state and local levels of

government, as well as in bridge, tunnel and turnpike authorities, civil engineering is the dominant ethos, and the orientation of the agencies is toward pavement and bridge engineering as opposed to traffic operations.

Metropolitan planning organizations march to still a different drummer. The planner's viewpoint pervades these organizations. Planners, being concerned with predicting and accommodating the future, tend not to be pragmatic and action-oriented. Until ISTEA, MPOs lacked funding authority, which distanced many MPOs from implementation and action. While ISTEA has greatly strengthened the role of MPOs by giving them greater decision making authority and power of the purse, it will be some time before most MPOs overcome their older way of being.

The academic community is oriented toward research and the writing of professional papers. It tends to be much less practical than either the public or private sector. The federal government has sought to make the academic community a full participant in the R&D, design, and operational testing phases of IVHS. However, overcoming the differences in work culture among the academic community and the public and private sectors has posed a challenge to some teams involved in operational tests.

Finally there is the defense sector, including defense companies and defense national laboratories. In comparison to the auto industry and many other private sector firms, defense companies are accustomed to working for a single client on a small number of very costly vehicles. Their profit margins tend to be much higher, and it is difficult to convince management to free internal capital for work in areas like IVHS. Defense firms and defense national laboratories are likely to be compartmentalized and secretive, which hinders team building and cooperation with others. Some of the defense national laboratories have large numbers of physicists with Ph.Ds and they are a unique breed of professionals.

To deploy IVHS in general and ATMS/ATIS in particular requires multidisciplinary skills and interdisciplinary teams, consortia, and other cooperate arrangements. Significant differences in work culture impede the formation of cooperative ventures, and once cooperative groups are formed, differences in work culture can impede their effectiveness.

What integrative strategy can overcome sharp variations in work culture? Organizational culture is well-known to be extremely resistant to change. The largest single inducement appears to be money, and in many cases money is not enough. The vast infusion of federal funds into IVHS research and operational testing has prompted many people who would otherwise have been wedded to their organization and culture to work with people of very different orientations. Where money is not sufficient to break down cultural barriers, some other strategies can make headway. One is to use a facilitator who can speak the "language" of more than one culture and serve as an effective bridge. Another is to provide training and education to broaden individuals so they can assimilate a perspective different than their own. Another possibility is job exchange programs.

B. Multiple Jurisdictions

Perhaps the greatest barrier to the deployment of ATMS, and perhaps ATIS as well, is the large number of jurisdictions that comprise nearly all major metropolitan regions. Many

metropolitan regions have more than one state, more than one regional agency (MPOs, COGs and RPCs), several counties, and municipalities numbering in the dozens, sometimes pushing or exceeding a hundred. In addition there may be a number of transportation authorities and other entities.

Integrative strategies for overcoming the problem of multiple jurisdictions include:

- Further strengthening the role of the MPOs relative to their constituent jurisdictions.

- Franchising the deployment of ATMS and ATIS, or using other methods that would permit the private sector to transcend or cut through multiple jurisdictions.

- Building upon multijurisdictional teams and other cooperative arrangements that have already been established to carry out operational tests, incident management, and coordinated traffic management on arterial streets.

C. Turf and Organizational Fragmentation

Closely related to the problems of work culture and multiple jurisdictions are turf and organizational fragmentation. Organizations with distinct missions and work culture often fiercely guard their territory and resist intrusions or pressure for change. This resistance is sometimes enough to thwart overtures of cooperation for such undertakings as IVHS.

Turf problems also apply to units within an organization. In federal, state and local transportation agencies, the traflic operations unit usually plays second fiddle to units involved in highway construction and pavement work. The traffic operations unit frequently is not well-integrated into the organization and does not have the ear of top management to the same degree as other parts of the organization. In large public works departments, rather than being given greater resources and responsibility for installing, operating and maintaining improved traffic management systems, traffic engineers frequently have found their resources diluted as a result of being given responsibility for pavement markings, striping, and signs. Consequently construction and pavement units in these organizations continue to hold sway. They protect their territory and their current resources, and yield little to those with a vested interest in traffic operations and management.

In many smaller cities and counties, responsibility for traffic signals rests not with a traffic engineer in a transportation or public works department, but with safety officials, usually the police. In more rare instances, even fire safety and emergency medical service officials have the responsibility for maintaining traffic signals. Public safety officials usually have considerable political power at the local level. They usually control their own budgets and their programs are independent of transportation and public works agencies.

Another important piece of turf belongs to local agencies responsible for public communications. These agencies are responsible for intra-agency and police, fire, emergency telecommunications. These agencies also often oversee the provision of cable television in the

local community, usually through a franchise. Organizations such as the Los Angeles DOT often find that coordination is difficult with the public communications agency because of differing priorities. In emergencies public safety officials tend to give priority to police and fire departments, whereas a transportation department would be compelled to look after traffic. Merger of telecommunication responsibilities is unlikely in the face of competing priorities. One consequence of this balkanization is that establishment of optical fiber networks is often uncoordinated. Public communication agencies will establish networks to meet their own needs, while transportation agencies are busy laying conduit when they reconstruct roads or have specific needs that require laying optical fiber cable.

Traffic operations units need to be elevated in importance and become better integrated into many organizations. Top management must commit to achieving this integration. Federal and state funds can provide an incentive for local jurisdictions to raise the profile of traffic operations, but in many cases that will not be enough. Also, to date, inter-ties among public agency networks in metropolitan regions are generally lacking, but over time it is likely the networks will be connected together.

D. Governmental Hierarchy

Federal programs tend to reach first to the state level, and then to the regional and local levels. Each level of government exerts some influence over the program until it reaches the lowest level. Prior to the enactment of ISTEA, the states clearly wielded much greater influence relative to regional government, and it could be argued that states even had a disproportionate influence relative to local governments. However, local governments nearly always have a significant road and bridge program funded through local property taxes and other sources.

ISTEA has clearly focused responsibility for congestion and air quality management upon metropolitan regions. The federal government now allocates funds directly to the MPOs, and MPOs must develop Transportation Improvement Programs (TIP) consistent with realistic financial plans, congestion management systems, and air quality objectives. Consequently, the role of MPOs has been strengthened relative to the states. This has had the effect of bypassing part of the hierarchy of government to some degree, although states will still exert strong influence through their existing construction programs, their statewide planning process and their own management systems for congestion and intermodal transportation facilities.

Government initiatives flow not only from the top down, but also from the bottom up (see ***Chapter II.C).*** The governmental hierarchy can be a barrier for local and regional governments seeking federal assistance, since they may have to work through the intermediary of the state. Often the states can help to obtain funding but sometimes they stand in the way, since state priorities may differ from regional and local priorities, and the time to process federal funding requests through state government can be arduous and time consuming.

IV. CHAPTER FOUR — TIMING AND PHASES OF DEPLOYMENT

A. Patterns of Technological Diffusion

The classic pattern of diffusion of a new technology is typically portrayed as an S-shaped graph. Time is the horizontal axis and market penetration or degree of adoption the vertical axis. In the earliest stages of introduction, there are only very early adopters who test the waters in operational tests and in the first few true implementations. It takes some time before the market is persuaded of the new technology, and the number of adopters rise quite slowly, the left-most and slowly rising portion of the S-curve. Momentum suddenly builds as a large number of potential adopters become persuaded of the benefits of the new technology and undertake their own implementation, the steeply rising portion of the S-curve. Finally, the pace of adoption slows down, implementation has become widespread, and the market becomes saturated, the right-most and the other slowly rising portion the S-curve.

It is likely that deployment of IVHS will exhibit this pattern of technological diffusion, but this pattern is far too simple be of use in highlighting potential institutional barriers to deployment. In reality, IVHS involves large numbers of different types of technology that are in different stages of technological diffusion and evolution. Institutional barriers can arise because the diffusion of different technologies is out of phase, and because a technology is becoming obsolete as new and improved versions come to market. Some technologies such as video cameras for surveillance are already available and widespread. Other technologies such as bridges and routers for network interconnections, are in the phase of rapid diffusion. Still others are just gaining a toehold in the market such as transponders for automated vehicle identification. Still others are in the operational testing phase, such as routing and navigation aids that use real time traffic information. Finally, there are some technologies that are still in the R&D phase and only just beginning to be field-tested.

It would be felicitous if all these technologies evolved, diffused in lock-step, and were ready for deployment just when the public and private sector were prepared for widespread implementation. But this is not the reality. Moreover, the technologies impose certain imperatives upon the suppliers and users, the institutions involved in deployment. Older technologies imply older ways of doing things, and new technologies, new ways. Institutions are very much aligned to the older ways, and making the transition to new ways can be wrenching. In addition coordination and communication among different organizations responsible for implementation can be complex and challenging.

Take ATMS for example. Deployment of ATMS depends upon the availability of a variety of sufficiently mature technologies to permit real time traffic monitoring and control. The key surveillance technologies of loop detectors, video cameras, and probes are already available and can support initial implementation. Optical fiber and other cable systems can provide the telecommunications backbone connecting the traffic management center to surveillance equipment and traffic control devices such as signals, ramp meters and changeable message signs. However, if large numbers of different types of devices must be controlled at a site, current controllers such as the NEMA and 170 controllers need to be upgraded, perhaps with Virtual Memory Exchange controllers that have a suitable bus for tying equipment together. Associated with the current large installed base of NEMA and 170 controllers are public agency traffic engineers and signal maintenance technicians, as well as consulting engineers in the private sector who helped install

existing traffic signal and freeway surveillance monitoring systems. Those accustomed to the current technology, especially if it has been recently installed, will not cede easily to new technology if there is added cost. Furthermore, the institutional experience in the maintenance and operation of current urban arterial traffic systems has been highly problematic. Many local governments are hesitant to install more sophisticated systems when they have neither the resources to operate and maintain existing systems nor proof that the new systems will perform better than the existing ones.

Dynamic traffic control for ATMS will require new types of software. Public agencies and private firms in the United States have virtually no experience with real-time traffic control on a metropolitan network of roads. In many cities, where sophisticated traffic signal systems have been installed that can adjust signal timing in response to traffic levels, these capabilities are not used to their fullest because of lack of staff. Another manifestation of the lack of capability for dynamic traffic control in the United States was the need for the Fast-Trac operational test in Oakland County, Michigan to obtain software from Australia.

Constructing a traffic management center and linking it to surveillance equipment and traffic control devices is one thing, but integrating ATMS with ATIS, represents a quantum jump from the current state-of-the-art. Institutions have not yet evolved to make this jump, although the operational test in Oakland County, Michigan will make this leap using roadside beacons. Exchange of data between the roadside and the driver requires that roadside communication technology has evolved so it **will** work in a wide variety of harsh environments, ranging from severe winter snow storms to hot dusty desert regions. As discussed in Chapter 2, there are important institutional interests concerning the degree ATIS technology resides in the roadside infrastructure or in the vehicle. These vested interests will influence and be influenced by technological solutions, choices, and diffusion. It is one thing for technology to have evolved where it can meet the needs, but it is another for the institutions to have evolved to accommodate the technology. If the pace of evolution of technologies and institutions do not match, it could be construed as a type of institutional barrier to deployment.

B. Critical Path

For the deployment of ATMS/ATIS to proceed expeditiously, certain elements must be in place at a certain time in the future. Otherwise deployment is held hostage to the missing components. FHWA seems to have recognized the importance of identifying and adhering to the critical path in the deployment of IVHS. The critical path is as much a function of institutional factors as technological ones. For example even if operational tests establish the feasibility and benefits of IVHS, implementation cannot proceed unless such issues as liability and privacy are resolved, and procurement procedures are in place to permit local and regional governments to install all the requisite elements of ATMS.

C. Phases of Deployment

Additional insights regarding institutional barriers to deployment of ATMS/ATIS can be discerned by examining different phases of deployment to see if there are inherent non-technical problems.

R&D, Design and Operational Testing. It is not strictly true to say that IVHS is currently in the R&D, design and testing phase. A small but not inconsiderable amount of implementation has already occurred due to efforts to build on existing systems, undertaking of operational tests, and efforts of the private sector to capitalize on early profit opportunities, especially involving commercial transport. Nonetheless, for all intents and purposes, IVHS is in the early stages of deployment characterized mainly by R&D, system architecture design, and operational testing. Major institutional issues and potential barriers to deployment are associated with each of these early phases of deployment.

Key institutional issues in the R&D phase are:

- the appropriate roles of universities, transportation research centers, federal defense and non-defense laboratories, private firms, and the public sector;
- the degree federal dollars should be used to leverage other funds;
- how research participants working in teams should share costs;
- protection of intellectual property rights including patents and software;
- government "march-in rights" to ensure that the fruits of federally funded R&D reach the market place;
- incentives to spur commercialization of products developed through R&D;
- and the extent to which R&D findings should be publicized and shared among the public and private sectors as well as with other countries.

Failure to resolve any of these issues in a thoughtful manner could retard the deployment of IVHS.

National System Architecture. A great deal of careful thought has surrounded the national system architecture effort which has just commenced. The federal government has awarded contracts for four simultaneous investigations of requirements for a national system architecture. Initial concepts will eventually be synthesized and integrated into a single national framework. The intent is that it will probably be an "open" architecture able to support a wide variety of evolving technologies and telecommunications, and it will probably include an open system reference model similar to the seven-layer OSI reference model for system interconnections. The national system architecture effort has already resulted in numerous institutions that will be party to its execution. These include committees of the IVHS America, a national IVHS consensus building effort, and the complex program management structure being used to manage the overall effort.

If the institutional structure proves to be ill-conceived, which is unlikely, or the various players have difficulty coordinating properly, it could hinder the deployment of IVHS. Potential problems may also arise in assimilating the huge amount of input from different quarters with various institutional interests and the melding of different system architecture concepts offered by the various contractors.

Construction, Installation and Operation. IVHS is unlike highway construction, in that operation does not occur independently of building the facility. For ATMS, construction of facilities, installation of equipment and telecommunications, and operation are intimately related, and each cannot do without the other. The institutions associated with each of these elements are rather different and need to be coordinated, which imposes unique institutional challenges. Left unmet, these challenges will become institutional barriers.

If the past is prologue, the contract construction industry is likely to build traffic management centers for ATMS. Contract construction might occur under many different procurement procedures. One is the public agency would design the facility and tender a low bid contract. Another is for a public agency to let for bid a "design-build-construct" contract. The construction contractor may or may not install equipment and telecommunications for ATMS. Most likely the construction contractor will subcontract for the professional services to install equipment and telecommunications and develop software, although the public agency might contract directly for such professional services. In rare instances, the public agency might even install the loop detectors, cameras, and conduit itself. It is unlikely, however, that the construction contractor will also operate the system, although the design-build-construct contract could be extended to include operations. Operational responsibility will most likely remain with the public sector or be contracted to a firm with traffic management expertise. It is obvious from merely listing some of the possibilities involved that, institutional friction could stand in the way of rapid deployment of ATMS.

Making ATIS operational is not so problematic, because it does not require construction of buildings. It is likely to require roadside infrastructure to integrate ATIS with ATMS, and so companies engaged in installing sophisticated roadside telecommunications will be needed. Most of establishing ATIS implementation will consist of developing data bases and connecting networks. Data base development and networking are not inherently problematic because the private sector is likely to handle this part of deployment except for real-time traffic data.

Maintenance. The concluding phase of IVHS is maintenance. As mentioned numerous times already, maintenance promises to be one of the most troublesome elements of deployment. Many of the most important concerns were outlined in the Urban Institute's study on IVHS staffing and education needs. Currently there is a shortage of personnel within public agencies (and possibly also in the private sector) with the requisite skills to maintain and operate many traffic signal systems that have already been installed in large metropolitan areas. This does not auger well for IVHS which aims to build and improve on these and related systems. The study on staffing and education needs enumerated some of the most important factors that will affect the future ability to maintain ATMS/ATIS. These include:

- System architecture options most favorable to maintenance, especially the degree to which IVHS should rely on in-vehicle equipment and wireless communication versus roadside infrastructure and wire telecommunications.

- How best to insure lifecycle costs are fully considered in the planning and design process, especially in light of ISTEA requirements that states and MPOs consider lifecycle costs.

- Whether Congress should exempt IVHS from the low-bid procurement process.

- How to ensure agencies responsible for maintenance have the requisite quantity and quality of staff when faced with hiring ceilings and wage caps.

- The relative roles of the private sector and different levels of government.

- How to fund maintenance at the regional and local level.

- Steps to ensure the reliability and quality of systems, including statistical process control, expert systems, and automated diagnostics and repairs to minimize maintenance needs.

- The potential role of an infrastructure management system for IVHS maintenance similar to those used for pavements and bridges.

- The role of incentives to maintain, and, sanctions and penalties for failing to maintain federally funded systems.

V. CHAPTER FIVE — OTHER INSTITUTIONAL ISSUES AND POTENTIAL BARRIERS TO DEPLOYMENT

This chapter addresses additional issues and potential barriers to the deployment of ATMS and ATIS, focusing on comments provided to the U.S. Department of Transportation in regards to the docket on non-technical constraints to the implementation of IVHS, the results of a literature review, and results of interviews.

This chapter is organized into three parts: 1) public sector issues, 2) public/private issues, and 3) private sector issues.

A. Public Sector Issues

1. Metropolitan Planning Organization (MPO) Issues

Although the MPOs have been required since 1970 to have a continuous, comprehensive, and coordinated (3C) process for cooperation among agencies at all levels, and there has been a federal urban aid highway program, the MPOs have had relatively little clout compared to most states until the passage of ISTEA.[5] ISTEA provides MPOs with funding authority for the first time and strengthens the role of MPOs in planning and formulating Transportation Improvement Programs (TIPS).

The key to successful implementation of IVHS around the country may lie in fully exploiting the MPOs' new status, power of the purse, and planning, programming and funding authority. Relevant issues are:

- whether there will in fact be a shift of power and authority from the federal and state levels to the regional level, and the likely pace of such a shift;
- the feasibility of using the mandated management systems for considering, advancing and obtaining funding approval for IVHS initiatives;
- the capability of the MPOs to carry out the complex intergovernmental coordination necessary to implement each category of IVHS, and the risks of over-reliance on MPOs as the avenue for implementation of IVHS;
- and the complementary coordination strategies required of other levels of government.

There is wide agreement in the IVHS community that improved area-wide coordination of planning is feasible, desirable, and probably necessary;[6,7,8,9,10,11] also, there is substantial agreement that this coordination should be voluntary, not mandated.[12,13,14,15] Many believe that the coordination task should be assigned to existing groups, e.g. MPOs, and that additional coordinating agencies should not be created.[16,17,18,19,20] Others go further to include operational roles, including traffic management or incident management;[21,22,23] some go less far, suggesting that regional traffic management centers are unnecessary and that a network of coordinated centers should be effective, or that jurisdictional coordination can be accomplished

at the staff level, without transferring local responsibilities to regional authorities.[24,25] Finally, some note that multistate projedts raise a variety of difficult issues, including differences in state views on project benefits, objectives, regulatory processes, and approaches to privatization, as well as the legal authority of states to enter into certain consortia.[26,27]

2. Management Systems Mandated by ISTEA

Another potential barrier to the deployment of IVHS arises from the requirement of ISTEA that every MPO in metropolitan regions with more than 200,000 people, and every state, implement six management systems and a traffic monitoring system. One of these is a congestion management system. An Interim Final Rule was issued on December 1, 1993 setting out the requirements for congestion and other management systems. The Interim Final Rule requires that MPOs and states develop and implement on a continuing basis a congestion management system that results in the identification of implementation of strategies that provide the most efficient use of existing and future facilities where congestion is occurring or is expected to occur. States and MPOs must evaluate the effectiveness of each congestion management action before inclusion in the TIP. These actions will include ATMS and ATIS initiatives; thus they must be evaluated alongside all the other options. Projects addressed within the congestion management system will be subject to great scrutiny, perhaps the same as those included in an MPO's TIP.

Congestion management systems are not the only management systems related to IVHS. Pavement and bridge management systems (also mandated under ISTEA) result in program recommendations for road work, and road work causes congestion. Eventually bridge and pavement management systems will have to be coordinated with congestion management systems. As the AASHTO Guidelines for Bridge Management Systems point out, in the long run states and MPOs may want to develop a real time bridge management component to communicate expected congestion caused by road work to travelers via IVHS, or more specifically through ATIS.

Safety Management Systems will need to be implemented under ISTEA, and IVHS is anticipated to have large safety impacts: perhaps only very modest accident reduction due to ATMS and ATIS, but certainly substantial accident reduction due to collision avoidance systems.

The remaining two management systems, which pertain to Intermodal Transportation Facilities and to Transit Facilities and Equipment also have a potential bearing on IVHS. Under the Interim Final Rule the effectiveness of actions that bear on intermodal facilities or transit facilities must also be evaluated. Some of the facilities, equipment and software used to improve intermodal and transit facilities will involve advanced technology deployed in IVHS.

The traffic monitoring system, also mandated by ISTEA, also has direct relevance to IVHS. The Interim Final Rule requires specified statistical precision of reported data, continuous counter operations, procedures for short term traffic monitoring, and vehicle occupancy monitoring.

The challenge states face in implementing all these management systems, many of which are new concepts and only barely defined, complicates the deployment of IVHS. Public agencies have very scarce planning staff. Resources that might otherwise be devoted to IVHS may be directed at implementing these management systems. Public agencies may simply be overwhelmed with all the planning and programming requirements of ISTEA and the Amendments to the Clean

Air Act. Fragmented agencies, internal turf, and other traditional problems impeding coordination might stand in the way of any 'kind of reasonable progress.

Hopefully public agencies will see all these requirements as an opportunity to improve and coordinate management tools and decisionmaking for transportation in general and IVHS in particular, but the opposite could very well be the case.

3. Contracting Issues

IVHS projects that are regional in nature may transcend the authority of a single agency, and may also cross state lines. Although regional projects may have significant benefits, legal problems arise from the sharing of agency authority with regional entities. Examples are:

a) whether the agency has the power to 'subdelegate' power to a regional entity or consortium; and

b) whether that regional entity exercises such broad powers that it requires Congressional approval under the Compact Clause.[28]

Both the private sector contractor and the public agency purchaser need to know that the other party has the authority to deal.[29]

Contracting issues are treated only briefly in this chapter. A more extensive discussion of contracting and procurement issues is given later in ***this*** report ***(see Chapter V.C.4).***

Subdelegation. The courts generally take a common sense approach to subdelegation authority, based on whether the delegation is necessary and on whether the legislature applies adequate safeguards, requires sufficient accountability, and exercises sufficient oversight. Clearly it is more difficult to meet these tests if the regional entity includes agencies outside the state and beyond the reach of state courts and controlling agencies; in such cases the agency seeking to delegate its authority may seek specific authority from the legislature, or may limit the delegation in various ways.

The problem of delegation of authority can be solved. For example, the organizers of the FAST-TRAC project in the State of Michigan (a wholly intrastate project) assumed that IVHS might require new statutory authority, but found that existing legislative authority was sufficient.[30] Michigan law provides authority for county road commissions to interact with their state and municipal highway counterparts to carry out the responsibilities of all, including contracting with one another. The law provides that the state transportation department has control and jurisdiction over all traffic control devices when a state highway segment is involved, and that the road commissions have similar authority at intersections between county roads and city streets. These carefully defined lines of authority, together with many years of cooperation, have created working relationships that have proved adequate for the IVHS project also.

Compact Clause. Interstate agreements that enhance the political power of states at the expense of federal authority are prohibited under the Compact Clause of the Constitution unless Congress consents to the arrangement. Absent Congressional consent, these arrangements may be acceptable if there is no delegation of the sovereign power of a state; if the state is free to

withdraw at any time; or if the federal government retains the power to overrule the group of states.

For IVHS, Congress in ISTEA retained federal authority over the Interstate Highway System and over standards and protocols; it also granted specific consent to the establishment of MPOs (but not explicitly to operating agencies), so long as their activities do not conflict with federal law.

4. Location and Mapping Issues

Most state DOTs and many regional and local governments have embarked on the development of Geographic Information Systems. Many agencies not only wish to exploit this new mapping technology, but also view GIS as a platform that can help integrate various organizational units and their decision support tools, including the management systems mandated under ISTEA.

Yet most public agencies have not properly thought through the requirements and specifications needed if GIS is to serve as a highly integrative tool. Some of these requirements and specifications relate to those used in digital maps being developed for use as in-vehicle navigation aids. The failure of public agencies to fully appreciate the relationship between digital cartographic base maps used in GIS and digital maps used for in-vehicle navigation is arguably a drag on the deployment of both.

Standards for digital maps, especially to ensure that IVHS digital maps and those developed by public agencies such as state DOTs are compatible, are important. There are many institutional issues concerning the locational accuracy inherent in digital maps used for IVHS and GIS. One of the most important of these concerns the reference systems used to relate elapsed distance over the ground to geographic coordinates. Transportation agencies do not have consistent elapsed distance reference systems. Some use mileposts, others use reference points associated with control sections, and still others use link node systems. There may also be a myriad of geographic coordinate systems in use in an agency, for example latitude longitude, state plan coordinates, and NAD 83. Not too long ago one investigator noted that the Michigan DOT used 38 different reference systems.[31]

The plethora of reference systems has spawned a huge amount of confusion and made the implementation of GIS exceedingly complex, because there must be a way to convert back and forth between elapsed distance and geographic coordinates while preserving ground truth (i.e., locational accuracy with respect to geodetic datum or survey benchmarks). Now along comes IVHS, and in addition the U.S. government is requiring all federal agencies to convert to the metric system by 1996. IVHS digital maps will create a tension with respect to digital maps already implemented by agencies as a result of their differing locational accuracies. The metrication requirement will ripple through state, regional, and local transportation agencies which depend heavily on federal transportation funding. Metrication will result in establishing a whole new reference system for use both internally to these agencies and externally by the motoring public and commercial transport.

Under Department of Defense specifications, stand-alone GPS receivers which operate under selective availability, the mode intended for civilian use can measure location in geographic coordinates with an accuracy of 100 meters 95 percent of the time. To date many in-vehicle

navigation aids use GPS as part of the navigation system, but a stand-alone GPS receiver is insufficient for achieving the requisite locational accuracies. However, when a GPS receiver is used in conjunction with a base station placed at a known point (a geodetic datum), and differential processing is used, survey level accuracies of better than 1 centimeter can be achieved if there are no obstructions in the line of sight to the satellites, and 5 meters appears to be quite feasible even if the roving receiver is moving at 55 miles per hour. Differential GPS may prove to be the tool to ensure the coincidence between points and elapsed distances represented on a digital map and those in the real world. Similar or better accuracies can be achieved with a stand-alone receiver if DOD turns selective availability off as DOD did during the Gulf War, or with a receiver that uses the precise code restricted for the military. One day the military may turn selective availability off except in wartime or may abandon restricting the precise code to itself because either the civilian sector will have found alternative ways to achieve the same level of accuracy or because the civilian benefits of widespread public access to the precise code greatly outweigh trying to limit our adversaries from having access to highly accurate locational technology.

Assuming differential GPS is required for digital maps with ground truth and highly accurate navigation, the economic cost of obtaining accuracies on the order of 5 meters or less is partly dependent on the existence of a web of base stations. Establishing a suitable set of base stations has proved to be a major institutional challenge because of the large number of state, federal and international mapping organizations involved. Many states are now involved in developing high accuracy reference networks (HARNs) that can serve as the infrastructure of base stations to support GPS. And eventually there will be a national and an international network.

These mapping issues are not an implementation barrier for IVHS. Manufacturers of in-vehicle driving aids have already developed digital maps with acceptable accuracy for many if not most driving situations. In-vehicle navigation aids depend for their accuracy upon such techniques as GPS, dead reckoning, and map matching. Nonetheless there are important institutional issues that overlap the implementation of IVHS and GIS, and they are worth some attention. If they are ignored, the public benefits and the private profits will be lower than they would otherwise be.

B. Financial Constraints to IVHS Deployment

1. Allocation of Resources

Institutional issues aside, the principal barrier to adoption of IVHS is cost. There is no better indicator of a public agency's potential objection to a proposed action than the funds demanded of (or withheld from) that agency. There is no better solution to such objections than to supply the required funds. Accurate assessment of the capital and operating cost of IVHS, and an acceptable allocation or sharing of these costs to public agencies at all levels[32], will be essential to gain acceptance of the IVHS program.

States and MPOs will face some difficult budget choices, and may be forced to choose between maintaining their existing infrastructures and adding IVHS technology. Maintenance has always been shortchanged at the expense of capital improvements, but the longer it is neglected the sharper will be the choice. Also, states must allocate funds between urban and rural areas, and among MPOs. Conflict of this nature may be one of the greatest obstacles to deployment of IVHS.[33]

Funding alternatives available to local communities should be explored as well. IVHS must compete for funds with a variety of other programs, many of which are unrelated to transportation. It would probably be helpful to such communities to have a well documented summary of the potential sources of funds for IVHS, including the less than obvious sources (e.g., charges to users for automatic intervention to avoid an imminent accident, ***etc.)***[34]**.**

2. Allocation of Risk

Closely akin to allocation of resources is the allocation and management of risk.[35] Communities serving as experimental sites may have little control over the scope or operations of the experiment, but may nevertheless incur substantial costs in hosting them or carrying them out. This is potentially a larger burden if the experiment is judged a failure, or leads to a result that is of little use to the host community. It may be desirable to provide for compensation or other protection for the community in such cases.

Similar issues may arise in the deployment phase of IVHS. System architectures will probably be imposed by the federal government, and technologies will probably be developed by private firms; these characteristics are largely outside the expertise of most communities, as well as outside their control, and failures of either function or applicability to local needs may require protection of these communities.

3. Stimulus for Economic Development

IVHS is potentially a strong stimulus to economic growth:[36] in the short to medium term by creating jobs in the process of its own deployment, and in the long term by increasing the efficiency of the nation's transportation infrastructure. Further benefits could be realized by coupling IVHS to the developing telecommunications and information infrastructure. Documenting the prospect for such stimulus (especially the long term effects) would both raise the level of public interest in IVHS and improve its likelihood of approval as a major program.

4. Site-specific Impact

The impact of IVHS may be significantly different in different areas, based on population distribution, land use, ***etc.*** IVHS may also affect metropolitan area growth development patterns, urban sprawl, and other demographic characteristics.[37] Depending on the particular services, architecture and implementation chosen, these effects could be favorable or unfavorable. To improve the likelihood of adoption of IVHS, and to improve its impact on society and the economy, these issues should be examined with care.

5. Staffing and Training

Different IVHS system architectures may impose different staffing and training burdens on state and local governments. It may be important to consider the impact of the various alternative system architectures on state and local governments, and to provide for appropriate assistance if a particularly burdensome design is chosen.[38]

In addition to staff related skills, IVHS may impose requirements for improved organizational structures and competence. Some governments may need assistance in

understanding those requirements as well as in implementing them. Providing such assistance at an early stage in IVHS deployment could avoid negative consequences that might impede the progress of the program.[39]

C. Public/Private Sector Issues

If private sector participation is central to the successful deployment of IVHS, the problem of coordination and interoperation between the public and private sectors is central as well.

It is axiomatic that government and private sector incentives are fundamentally different. Our economy offers many examples of mechanisms for the mobilization of the private sector to achieve public objectives, while limiting the adverse side effects. Some of these mechanisms have worked well, and some have created problems that have taken decades to solve. Virtually all have arisen as the result of private initiatives, in which the largesse or forbearance of government has been sought by business, or have been imposed later by government to solve a problem created by unrestrained private activity. The new aspect of IVHS planning is the affirmative effort of government to seek a workable mechanism at the outset.

Possible mechanisms cover a wide range. At the traditional extreme is simple contracting, in which government decides what it needs, develops a project plan and a specification, seeks bids, and awards a contract. If the process is conducted well the government gets what it really needs, the bidder makes a profit, and the project or system procured successfully fulfills its intended function. The boundary between government and the private sector vendor is clear, both from historical practice and from the particulars of the contract, and the costs and risks are typically incurred solely by the government.

A number of innovative procurement policies are currently under discussion as possible mechanisms to implement IVHS. These mechanisms generally rely on moving the traditional boundary between public and private activities. For example, private ownership and operation of facilities carrying out traditionally public functions (e.g., private toll roads or privately owned communications systems carrying publicly generated traffic information to private vehicles) establishes new public/private boundaries that alter the responsibilities, risks and opportunities on both sides.

One useful technique is to divide IVHS elements into those that are inherently governmental and those that are not inherently governmental. It may then be possible to divide the latter into those that are potentially profitable and those that do not look like promising business opportunities. Another is to divide potential private sector roles and responsibilities into categories, based on the constraints that government might impose, such as:

- roles forbidden by government
- roles not restricted by government ***(laissez faire)***
- roles required by government.

These and other similar attempts to divide the provision of IVHS capabilities into elements, and to examine each element for its impact on the success of the effort and for its public policy consequences, could yield a powerful and flexible policy planning tool to use in the complex public/private sector bargaining process that lies ahead.

1. Regulation of Economic Activity

At the heart of any institutional relationship between government and private industry is the regulation of economic activity. Few governments permit unfettered economic activity, especially if the enterprise is established to serve a public purpose, is organized at the behest of government and with its blessing, and involves a sharing of responsibilities with government. Thus the relevant issue is not whether the activity will be regulated (we use the term here in its broadest sense, ranging from an overall legal framework to control of common carrier prices and rate structures), but rather the degree and form of the regulation.

Whether regulation rises to the level of a barrier to implementation of the objectives of the business enterprise is thus a matter of detail rather than of principle. Government can successfully impose stringent controls on a private activity if it has no interest in the success of the activity itself, or views it as destructive; government does not shrink from draconian regulation of socially or economically disruptive activities (e.g., gambling, certain boiler room practices in stock promotion, ***etc.).*** But if government has an interest in the success of the activity, it will seek to avoid placing counterproductive limitations upon it.

The great majority of government regulation of private enterprise is thus undertaken to limit the undesirable side effects of an activity that is fundamentally desirable, or at least harmless. Generally the limitations relate directly to the perceived side effects. There is certainly no shortage of examples.

The central issue in regulation is usually the economic aspects of the activity itself. In broad terms, government seeks to assure an efficient, well-functioning market, and to safeguard the rights of both buyers and sellers. Within these broad boundaries lie numerous key issues, with strong believers on all sides of each. Thus, government regulates the rates of common carriers of all types to restrain monopoly providers of products and services from taking undue advantage of their market power, introduces antitrust limitations to keep businesses from draining off the economic benefits of competition, and to keep them from developing into ***de facto*** monopolies, and constrains deceptive withholding or dissemination of information that could distort economic decisions of consumers.

In common carrier regulation, one of the fundamental issues in recent years has been the choice between rates based on marginal cost (the particular enthusiasm of the monopolist that faces developing competition, supported by assertions of economies of scale) and on fully allocated cost (the brief of the would-be competitor, seeking a high fence to enclose his monopolistic nemesis). Both invoke the public interest to support their positions, and it falls to government to mediate the dispute.

Big is not bad, but big often confers great market power; undue collaboration between big players can give them undue advantage in the game of commerce against the small consumer or would-be competitor. Government relies on traditional regulation to protect consumers against a true monopoly, and on antitrust law to protect the competitive marketplace against the accumulation of excessive market power short of that required to invoke regulation. Thus it is the role of antitrust law to define the acceptable boundaries of market power, and of behavior that threatens to create such market power.

Government also places limitations on the dissemination and use of certain information (e.g., confidential information of individual citizens), and mandates the form, substance and timing of the release of certain other information (e.g., corporate information that could influence the price of the company's securities).

What do these traditional regulatory activities of government mean for IVHS? FHWA is taking a fresh look at the way government regulates transportation, hoping to remove institutional barriers to implementation of IVHS (this study project is a key example of this effort) and to stimulate the participation of the private sector in its development and deployment.

This is a landmark effort. Seldom has the federal government sought to establish a major domestic program to improve mobility and foster commerce, to create new business opportunities and minimize the associated risk, to consider seriously cooperative business/government ventures, and to ask business firms for their views on how the government should change its own policies and regulations to make it all happen. This sort of industrial policy is the norm in many countries, but seldom has it occurred in the United States.

The difference between IVHS and numerous other infrastructure elements is this intensive government effort to involve the private sector in the role of investor in facilities and services desired by government to serve the public interest. Government is seeking to induce businesses to take certain risks to help accomplish a public purpose, and is actively studying a wide range of regulatory and policy innovations it could adopt in return.

An inherent contradiction lurks just beneath the surface. Many of the private sector firms most likely to participate with the government as its IVHS partners are also likely to seek to become contractors on government funded portions of IVHS. This contradiction, an evident conflict of interest, must be resolved before these partnerships can be realized. To accept such partnerships in trade for abandonment of the benefits of full and fair competition may be a poor bargain ***(see Chapter V.C.4).*** One approach is to limit such partnerships to the R&D and design phase, and require competition in the deployment phases which the Europeans are doing in the PROMETHEUS project.

Where are the policy opportunities? From the viewpoint of business, the fewer government policies and the less government regulation, the better. Many businesses would be delighted, for example, to be given the keys to an important monopoly service without a commensurate regulatory framework. What well-financed private business would decline, for example, the opportunity to take over an extensive turnpike system with no limitation on its right to charge (no pun intended) what the traffic will bear? And what government would let this happen? Such an example is clearly beyond reason, but it illustrates the monopoly extreme of the policy continuum.

A more centrist example might be the delegation to one or more private businesses of certain exclusionary rights to profitable new services, along with appropriate regulatory restrictions on prices charged and conditions of service. These business entities might also be permitted to cooperate with one another in ways that are not presently permitted under the antitrust laws. This example lies well within the range of franchising, a key topic of this overall study. One need not prejudge the outcome of the study project to suggest that this is a fertile middle ground for policy development.

Another intermediate example might be various cooperative ventures between government and business, in which government would supply certain facilities or data, or grant certain access to government property, to create a revenue producing opportunity in which government and business could share. The creation of this opportunity, which would not exist without government stimulus and participation, might be sufficient inducement to the private sector to invest.

It is worth noting that, to the extent that economies of scale exist, an increase in demand leads to an increase in output and a decrease in cost; thus a mechanism that increases the incentive of the participating business to market the IVHS capability vigorously would be beneficial.

At the ***laissez faire*** extreme of policy, government might simply relax its traditional rights sufficiently to allow privately funded ventures at private risk, imposing only the controls on information and on externalities that are the minimum responsibility of government.

Although there may be policy opportunities at the extremes we have so briefly dismissed, the centrist range is broad enough to offer considerable promise. Note that the somewhat negative paradigm of overcoming barriers to IVHS deployment may be unnecessarily restrictive; a broader focus, embracing as well the various positive policy mechanisms available to the government, may create additional opportunities at very little extra cost in effort or attention.

2. Cost Recovery and Cost Allocation

There is no more central issue for a private sector entity than the assurance that it will be able to recover its invested capital and operating costs, and make a profit. This assurance need not be in the form of a government guarantee, but the overall structure of the venture, coupled with a clear view of the market and a clear idea of the anticipated cost, must yield a reasonable risk/reward ratio.

For government, the allocation of cost is equally important. By taking the initiative to promote IVHS and to induce the private sector to participate, government takes on much of the responsibility for the societal impact of the overall program. Few societal impacts are more controversial than an inappropriate distribution of costs and benefits.

An unregulated monopoly, the policy extreme cited above, would have no trouble achieving recovery of costs, assuming only that a sufficient number of users regarded its service as essential. Although lack of regulation would by definition preclude government influence over allocation of cost, the unrestrained monopolist could well end up serving only that narrow segment of customers for whom price is no object, the user group that least requires government protection.

The extreme unregulated monopoly case of course leaves unprotected, and possibly unserved, the great majority of potential users. If the service offered is considered essential by most users, this approach greatly disservices the public; if it is not considered essential, or if competing technologies or solutions are available, the service (and the provider) can quickly become irrelevant. At one time, government failure to regulate the price of telex service would have been a shocking omission: today, with the wide availability of computer modems, facsimile terminals, and data networks it is a service that has largely been forgotten.

At the ***laissez faire*** extreme, in which private initiatives are largely unfettered, society and government rely on the competitive marketplace to establish both the risk of failure to recover costs and the prices that relate to the underlying cost elements.

Thus the extreme and accordingly least likely implementation mechanisms for IVHS are in some ways best able to treat cost recovery and cost allocation questions. It is once again in the broad middle ground of policy development that unresolved issues arise.

In the more usual regulated monopoly case typical of publicly-awarded franchises, a private sector entity is guaranteed a reasonable return on its investment through the rate regulation process. Rate regulation may treat cost allocation as well, by requiring a rate structure that relates the prices paid by classes of customers or for elements of service to cost-causative factors.

Some aspects of IVHS may be demonstrably feasible with more than one competing private sector operator/investor, owing to the lack of economies of scale or to the availability of alternative technologies. In such cases, even though government may participate in a venture by offering access to its information or facilities, the government can rely on the normal competitive marketplace to protect consumers and (implicitly) to achieve cost recovery and satisfactory allocations of cost. This reliance is implicit in the sense that a private sector operator relies on an estimate of the marketplace in deciding the likelihood of recovering costs, and the consumer relies on the competitive market for protection from pricing artifacts unrelated to the underlying cost structure.

In summary, it is not necessary to reinvent basic economics to assure that IVHS costs are recovered and that prices are properly related to cost-causative factors. It is necessary to define a feasible public/private sector cooperative format for IVHS that is consistent with its objectives and technologies, and that appropriately matches risk and reward. Numerous well-understood mechanisms exist to assure that costs take their proper place in the chosen format.

3. Administrative Costs

It is easy to overlook the hidden administrative costs of a new industry structure. The cost of regulation has many elements, not always clearly visible even to the practiced eye. The costs of regulatory overhead are the simplest to define: government regulatory staff, private sector attorneys, and a small army of economic analysts and consultants are the stuff of regulation. What would otherwise be a competitive marketplace is transplanted to the special turf on which expensive experts plant and nurture arcane controversy. This is a wholly unproductive process, justifiable only if such factors as economies of scale can overcome these costs and still yield a net benefit to society.

Other administrative costs are more difficult to ascertain. For example, the regulated (franchised) entity may well delay investment in new facilities or equipment until the regulators permits cost recovery from the last investment cycle. Here the administrative cost, or more precisely the cost of administrative delay, results from the delay in introduction of additional or more efficient facilities. Regulators may also attempt to substitute their judgment for that of the franchisee, with the objective of limiting costs and rates; the result may be a cheaper but less efficient or capable service, with a higher cost per unit of useful output.

Perhaps the greatest hidden administrative cost is incurred instantaneously when the regulated monopoly model is adopted. By eschewing competition, government locks in the objectives, plans, technologies and resulting costs of a specific business entity, and forgoes the opportunity for competition to generate future cost reductions. This cost is at least as great as it is difficult to measure; one need look no further than the technological revolution in telecommunications that was unleashed when diminished regulation and the AT&T divestiture opened the market to competition.

4. Contracting and Procurement

IVHS will depend on a combination of new technologies, new programs, and new relationships among government and private sector entities. Existing lengthy and complex procurement processes traditionally employed for large transportation projects are both too cumbersome for these new technologies and badly matched to the new relationships on which IVHS will depend.[40,41,42,43,44]

Many of the problems arise from the fact that IVHS has not been completely defined, especially for infrastructure based systems,[45] and the fundamental policy decisions have not been made. The process of defining the roles of the public and private sectors has barely begun, so it should be no surprise that law and practice developed for more traditional public/private relationships do not fit the wide range of policy options presently being discussed.

IVHS policymakers generally ascribe to private sector firms the roles of system designer, builder, or operator; provider of risk capital; and of course seeker of revenue and profit. The public sector generally acts as the architect of public policy; as a provider of service to the public; as a provider of public funds; and as a collector of tax revenue. These are traditional roles for both sectors, but the new relationships between the two are potentially quite different, and confusing the roles could well confuse the relationships.

The potential conflicts of interest of private sector firms have been widely discussed, and deserve the closest attention as IVHS relationships develop to avoid the loss of important public benefits. Government properly has an interest in receiving objective system design advice from contractors, and typically assures objectivity by prohibiting design contractors from seeking implementation contracts. This is a logical practice for mature products in mature industries, but in high technology areas such as IVHS the most qualified potential design contractors might decline to participate in design work, to preserve their right to bid on major implementation contracts. Some believe that these regulations should be modified to allow technology developers to bid competitively on follow-on work, with appropriate protection against the possibility of collusion in the early stages of development,[46] or to have certain exclusive rights if they share the risks.[47] IVHS is surely not the only high technology area affected by these regulations, and may not qualify for an exception, but it would be appropriate to review carefully the impact of these organizational conflict of interest issues on the IVHS program.[48]

Government should also examine its own intended roles with care, since there are potential conflicts of interest within government as well. For example, it is all too easy for government to approach a potential relationship with a private sector firm from its unique vantage point of policymaker, when the actual interest of the relevant agency may simply be in providing a needed service or obtaining additional revenue. Thus a local agency might seek to limit access of private

sector firms to traffic information, perhaps on policy grounds, because it perceived an opportunity to gain revenue for the agency, even if the agency would be a less efficient provider of traffic information services than a private sector firm.

It seems well accepted that there is a need for institutional arrangements that will enable the private sector to develop profitable new products and services that will serve the public, and that uniform legislation and/or standards will be an essential part of those arrangements.[49,50] In particular, private sector firms will require much greater access to public facilities and information, and perhaps even ownership interests.[51,52] Sharing of responsibilities between the public and private sectors may be necessary,[53] but state and local ethics regulations may impede public/private partnerships.[54] A variety of proposals have been made for experiments with new public/private relationships, including giving private sector participants greater input into the public sector decisionmaking process; providing for joint public/private sector management committees; allowing for negotiated public/private rulemakings; and establishing joint public/private sector commercial IVHS services.[55] Successful partnerships should be offered as models for others to follow.[56]

Closely related to institutional arrangements is the definition of those services that will lie within the public and private sectors;[57] one proposal calls for the private sector to be responsible for vehicle based information or services, and for the public sector to be responsible for infrastructure facilities or services.[58,59] Some believe that private sector ownership or operation of a traffic management or information system is contrary to the public interest, or that IVHS should be provided on the basis of universal service, or should be free;[60] such beliefs seem fundamentally incompatible with the approach of public/private partnerships.

It is worth noting that there is nothing inherent in IVHS that demands either government or private sector participation, or in particular a partnership of the two. The issues are essentially generic:

- Is it appropriate in our society for government to provide services that can be provided with equal or greater efficiency by the private sector?
- Does government realistically expect to be able to offer the proposed services with public funds?
- Does government have the necessary technical expertise to offer the proposed services?
- Does operation of essential public services by private sector entities place too much power (e.g., control of facilities or access or personal data) in the hands of those entities? Would the role of the private sector in the provision of these services ultimately be analogous to the role of the telephone companies in telecommunications, or to the role of the insurance companies in health care?
- If private sector operation is contemplated, can sufficient competition be assured to avoid exploitation of the public?

- Are the services proposed for delivery by private firms regarded as essential? If these services are essential, how can government be assured that they will in fact be available to all? If they are not essential, should government pay more than cursory attention?

Multiple jurisdictions involved in a project can yield layered, overlapping and possibly conflicting regulations, causing delays and imposing cost burdens on private sector vendors. The federal government might assist such jurisdictions to exchange information on solutions to such problems. Also, if various jurisdictions could delegate their authority to a single operational agency, some of these difficulties might be avoided; such a solution would require an amendment to ISTEA under the Compact Clause of the Constitution ***(see Chapter V.A.3).***[61]

This is more than a theoretical problem. A number of IVHS experiments and early deployments have already experienced problems of this nature, leading to both increased costs and poor accountability for failures. A non-proprietary procurement environment, with a mixture of equipment from different manufacturers and without standardization, combined with a low bid procurement system designed for roadway pavement construction, virtually guarantees incompatibility. Also, for projects involving activities central to the purpose of the contracting agency (e.g., electronic toll collection for a toll agency), the agency may be extremely cautious, since a mistake could be devastating for its mission.[62] The lack of experience of public sector entities, general contractors and subcontractors with high technology projects adds further confusion; here the federal government could help by sponsoring training programs for state and local procurement staff and for businesses.[63,64,65] Government can also help to stimulate innovation through intentional purchases of new products in sufficient volume to encourage private sector investment.[66]

There are a number of ways to improve a situation that is the victim of multijurisdictional problems. Two are to either eliminate some of the competing jurisdictions or encourage them to cooperate effectively with one another. Also, interoperability of proprietary equipment built to volatile or evolving standards can be improved by careful attention to project wide systems engineering, carried out by an agency or contractor highly experienced with this role and with the new IVHS technologies-the "high tech" analog to the general contractor role in more traditional procurements (but often without the financial responsibility). This approach is well known in the NASA and defense procurement environment, and could be adapted to IVHS procurements, although the responsible agencies may need a good deal of training to apply the method effectively. Both government (NASA and DOD) and private sector assistance should be sought in this training effort, and the process will take time and persistence.

A contracting agency's acceptance of federal funds for IVHS brings with it a variety of obligations and restrictions, which complicate the procurement process and place burdens on both the agency and the contractor.[67] Contractors may be reluctant to accept the obligations of federal recordkeeping, as well as compliance with federal civil rights and labor law requirements. Federal intellectual property claims ***(see Chapter V.C.6.b)*** are a potentially major problem.

Experience suggests that problems such as these arise largely because of unfamiliarity of IVHS vendors, new to the road improvement project process, with both the various regulations and the government agencies themselves. Although some private firms hesitate to become involved

in this process, better communication of the various requirements to this new group of vendors would go a long way toward solving these problems.[68]

Another major problem is the cost of compliance with the myriad of federal cost accounting, cost certification and auditing requirements. Large procurements often lead to the need for new accounting systems, as well as specialized and costly accounting experts. Requirements for recordkeeping, special reports of many kinds, other special requirements imposed on government contractors, and government's demand for products tailored to government needs and thus different from the contractor's commercial products, the insistence of government on the right to terminate a contract for convenience, the uncertainty of the political appropriation process, and repeated revisions of procurement by agencies seeking the latest technological developments, all add to the cost of doing business with the government. Also, the frequently used device of a separate subsidiary to insulate a company's commercial business from federal contracting requirements may not be feasible for IVHS, since the technologies to be used have both commercial and government applications.[69]

Some agencies and industry experts believe that many of the government acquisition requirements would not significantly impede the development of IVHS if suitable voluntary technical standards were available.[70,71] Others believe that such regulations can delay IVHS, and that changes are warranted for this or other reasons (possibly with a sunset provision).[72,73,74,75,76,77,78,79]

Although these problems can be solved with attention and experience, both new approaches and thorough training of government managers, business executives, and attorneys will be needed.

A better and more general solution to most of these problems might be to remove government agencies (whether one or many) from the entire process by defining as much as possible of IVHS implementation to be a competitive private sector task. Although there are ample opportunities for such an approach to lead to socially unacceptable consequences, the private sector is more likely than government to be flexible and efficient in implementation. If the various jurisdictions focus vigorously on policy and leave implementation to the private sector, IVHS could be made both to serve the public interest and to operate efficiently.

5. Opposition from Competitive Technologies and Industries

Roadway transportation has always been directly competitive with industries based on other technologies such as railroads and airlines, and these industries are the natural enemies of highway improvements.** The continuing decline of the railroads, and the more recent difficulties of the airlines, sharpens the conflict significantly. Thus the railroad and airline industries, further disadvantaged by the prospect of a major government led IVHS initiative, may be expected to be bitter opponents. Congress, faced on one hand with proposals for deficit financing of multibillion dollar IVHS expenditures, and on the other with implacable opposition from vocal competitors, may tend toward ambivalence.

Also, there are good public policy reasons for a balanced transportation policy. If IVHS succeeds at the expense of other technologies, the nation may find itself with a less than optimum transportation mix. The result could be to skew the transportation sector and the economy in an inefficient direction, to begin yet another long term cycle of dependence on foreign owned fossil

fuels, or to exacerbate transportation's impact on the environment. Thus opposition on policy grounds can be expected as well.

The IVHS program will probably survive the opposition of competitive industries, and can probably be made consistent with a balanced transportation policy. But such a costly and long term initiative needs all the friends it can get, and such opposition should be taken into account at an early stage in the planning process.

6. Legal Issues

The new forms of public/private relationships contemplated for IVHS, and the potential for legal exposure arising from placing the safety of large numbers of drivers under the control of privately owned or operated transportation systems, create a variety of novel legal problems. Some of these could significantly impede the deployment of IVHS. Also, placing business in a newly ambiguous relationship with government, one which requires business to invest its capital in a venture that serves government objectives, raises the question of a parallel allocation of the benefits of the relationship. And unrestrained collaboration among competing businesses, even in the service of government objectives, creates a potential opening through which otherwise proscribed behavior can enter. These issues are outlined below; certain others that relate to matters treated elsewhere in this report (e.g., legal issues related to contracting) are discussed in the context of those matters.

a. Tort Liability

Some IVHS implementations would place privately-built or operated equipment in sensitive spots that can create legal liability. An accident involving loss of life that is traceable to a design flaw in the vehicle's braking system is almost as much a nightmare for the automobile manufacturer as it is for the families of the victims. If the failure is in a collision avoidance radar system that causes a 50 car accident at highway speeds, nightmare is too weak a word to describe the legal consequences. It may be that IVHS cannot develop along the lines presently being discussed unless some changes in the tort liability situation are achieved. A number of reduced liability scenarios have been proposed, among them an analogy to the international convention on airline liability. In some cases, existing legal doctrine may be sufficient to permit the development of IVHS while affording adequate protection to the public. Proper treatment of this issue may be essential to the full development of other IVHS business opportunities. Finally, in those cases involving a contractual or collaborative relationship between public agencies and private firms, the matter of allocation of liability is both important and controversial. Thus a full treatment of tort liability for IVHS must include the potential sources of liability, the specific IVHS products or services that might be foreclosed under existing law, the possible limitation of liability, and the allocation of the remaining liability among IVHS participants.

One cautionary note. Most of the vocal participants in the IVHS policy dialogue to date have been government agencies, researchers, and consultants; there has been relatively limited participation from the business community. The material reviewed in this report necessarily reflects that imbalance. Government agencies have their own special viewpoint, and researchers and consultants do not always have the experience or perspective to reflect the concerns of the business community; yet we count on business for much of the initiative and investment required

to make IVHS succeed. Accordingly, policymakers should avoid rushing to conclusions about matters such as tort liability that may turn out to be of major concern to the private sector.

It is equally fair to note, without detracting at all from the participation of FHWA and other federal government representatives that are their first line of defense, that the public at large has been underrepresented in this process. There is no question that the public will have its day in the court of last resort, the U.S. Congress; it would be to the advantage of the IVHS community as well as the public to integrate the views of the citizenry into the planning process much earlier. We should also avoid equating the public interest with the interests of the trial bar, often its most aggressive symbol.[81] The long term character of the IVHS initiative, and its unavoidably long gestation period, should offer plenty of opportunity for public education and dialogue. That dialogue should be forthright and truly bidirectional, to maximize the public benefits of IVHS and to accommodate public concerns before they can crystallize into organized opposition.

Although IVHS is at an early stage of deployment, some preliminary conclusions have been suggested.[82] First, existing case law relates primarily to ATMS; the potentially major legal consequences of ATIS have not been treated. Second, there is no discussion of existing case law relating to private sector IVHS operators. Third, the lack of case law specific to IVHS makes it difficult to prove the existence or lack of existence of major liability problems, but it creates uncertainty and fear that at present constitute the greatest liability deterrent to IVHS. Finally, it is important to consider separately the liability of each class of IVHS participant: government at all levels, manufacturers, and drivers.

Some early experience with IVHS suggests that liability issues have not been a problem. The FAST-TRAC project in Michigan has so far not increased the liability exposure of the Oakland County Road Commission, which is already liable for failures in its more traditional traffic management systems, and private sector participants in the project so far have not expressed substantive concerns.[83]

Tort liability affects many different IVHS interest groups: to help focus the discussion, we outline below the interests and views of each major group, and the potential impact.

Federal Government

The federal government inherently enjoys sovereign immunity from suits, but has generally waived this right under the Federal Tort Claims Act. This waiver applies to any wrongful act or omission by a government employee if a private person would be liable under the same circumstances. This waiver does not apply to the executive planning level of government. Thus federal liability would probably be relevant only if the federal government were the actual operator of an IVHS system, a relatively unlikely possibility.

State Government

State governments also enjoy sovereign immunity, and have also generally waived this right (though not uniformly). Thus if a state actually operates an IVHS system it may have liability exposure. With some exceptions, the eleventh amendment bars private suits against a state in federal court, although appeals to federal courts are permitted.

Municipal Government

Municipal governments are generally liable for the acts of their employees (except for such fundamental acts as passing legislation or providing police protection). Suits in federal court are permitted. Thus if a municipality actually operates an IVHS system, it too may have liability exposure.

Manufacturers

Manufacturers of ATMS or ATIS equipment are subject to product liability for a variety of types of claims, including alleged failure of the system to provide timely needed or promised information (e.g., a hazard warning), or for providing information jeopardizing the driver's safety (e.g., directing the driver onto a collapsed bridge). Manufacturers may also have liability under contract law.

Manufacturers' liability can be divided into manufacturing defects and design defects. The manufacturer is generally subject to strict liability in the case of manufacturing defects, but this liability is generally tempered with balancing tests in the case of design defects. In the latter case the manufacturer is usually liable if the consequences of the design failure could have been foreseen. Manufacturers may also be liable if they fail to install existing safety equipment on all of their vehicles; thus a manufacturer may have a disincentive to offer expensive safety oriented IVHS equipment, because of the implied obligation to provide it universally.

The Federal Highway Safety Act set motor vehicle safety standards for passenger restraints, thereby both giving manufacturers a choice between seat belts and air bags and pre-empting suits against them in state courts. At present there are no similar pre-emptive standards specific to IVHS technology.

Manufacturers are concerned about the uncertainty regarding allocation of liability as well as the liability itself; these concerns will affect both the willingness of manufacturers to participate in IVHS and their prices for products and services.[84]

Although liability issues are potentially a serious impediment to full development of IVHS, remedies and solutions are available. The federal government could indemnify vendors from liability-NASA and EPA have both taken this approach in certain cases-or limit their liability. In some circumstances, contractors that comply with government specifications can benefit from the sovereign immunity of the government itself. And insurance, offered either through private insurer or by means of a government risk retention pool, might provide protection without a fundamental restructuring of the liability laws.[85,86] Opinion in the non-manufacturer part of the IVHS community is mixed: some favor limiting liability exposure;[87,88,89,90,91] some are open minded;[92] some are skeptical;[93] others believe that technical standards will yield a solution;[94] and some are adamantly opposed.[95] Some manufacturers do not anticipate problems.[96]

Drivers

Regardless of traffic signals or instructions, the driver of a vehicle has the duty to exercise due and reasonable care. A green light is not a command to go; it is qualified permission. Thus operators, manufacturers, and drivers all share the liability for failures of ATMS.

For ATIS, the situation is less clear. Case law regarding aircraft navigation and information receiving systems may be applicable to ATIS-the radio beacons, air traffic information transmissions and weather information broadcasts provided for aircraft are similar to ATIS information provided to vehicles, and aviation proximity detection equipment is similar in concept to AVCS collision warning/avoidance devices.

b. Intellectual Property Rights

If government provides major funding for IVHS, and contracts with businesses in the usual way, the treatment of intellectual property developed in the course of these contracts is appropriately established in existing law. That is much less true if business is expected to risk its own capital to help make IVHS a reality. New compromises must be made to account for the dual interests of government and businesses in the intellectual fruits of joint research and system development. The proper balance will depend on the particulars of the technologies and the financing methods, and may differ according to the IVHS system or application being considered.

There are three significantly different types of financial relationships between government and the private sector, each based on different assumptions, and each leading to a different set of issues:

Traditional Contracting

- limited intellectual property component
- cost of the procurement is based on other elements
- government pays the full cost of the procurement.

Defense and NASA Contracting

- substantial intellectual property component
- cost of the procurement is based in large part on the cost of the intellectual property
- government pays the full cost of the procurement
- vendor recovers its full intellectual property cost under a single program from a single government customer.

Possible IVHS Contracting (cost sharing or partnerships)

- substantial intellectual property component
- cost of the procurement is based in large part on the cost of the intellectual property
- government pays for only part of the cost of the procurement

- vendor cannot recover its full intellectual property cost under a single procurement.

Each of these approaches is discussed briefly below.

Traditional Contracting. In traditional contracting, in which a government agency pays the full cost of the products and services, and in which the intellectual property component is limited, it is easy to conclude that the government is entitled to whatever incidental intellectual property is necessary to achieve the benefits of the purchased products and services. Most contracting regulations are written with this case in mind, and many of the expectations of local and state transportation authorities regarding intellectual property are probably based on this type of contracting. Such cases do not lead to controversy.

Defense and NASA Contracting. In most defense and NASA contracting (e.g., R&D contracts or high technology weapons or space procurement), intellectual property comprises a substantial part of the overall contract effort. The intellectual property would not have been created except for the particular contract, the vendor is fully compensated for the cost of developing the intellectual property, and in any event it is unlikely that any other customers for like products even exist. Again, such cases do not lead to controversy.

Possible IVHS Contracting. The IVHS contracting approaches most often discussed differ substantially from the above well known cases. First, the government anticipates that the private sector will invest substantial capital in the development and deployment of IVHS technology and systems, in the form of cost sharing or other forms of partnership between the public and private sectors. Private sector firms have in many cases already developed these technologies at their own expense, well in advance of significant government contracting activity. It is unlikely that these firms will be able to recover their investment in this technology from a single government contract, and in most cases they don't try to do so; they count on the possibility of a number of future contracts with other government agencies to recover their development costs and to earn a profit. Thus these firms are extremely reluctant to enter into contracts that require them to grant rights or licenses to their intellectual property to the government, and possibly even to the public.[97] Some ask that IVHS be based on an open architecture that would assure government agencies of multiple vendors, while permitting individual vendors to protect their proprietary implementation by means of patents.[98]

Government transportation agencies have opposing concerns. First, they are properly insist that they are entitled to a continuing right to the use of the software, specifications, documentation, and other intellectual property required to operate the purchased system or equipment, to expand it and/or repair it if necessary. They are understandably concerned that the system might fail, or the vendor might go out of the JVHS business, leaving the agency with an orphan system.[99] Such agencies tend to be risk averse, and also tend to have the market power to demand legal protection from such possibilities.

A good example is orphan software code[100]. A contracting agency may demand that the vendor place a copy of its software in escrow, to be released to the agency if the vendor defaults on its obligations under the contract. This demand may extend beyond software to the full range of documentation that the agency might need to operate and even manufacture the overall system. Also, it may be necessary to provide for testing or other evaluation of the escrowed software, and

to protect the escrow agent from liability. The contracting agency may also seek indemnification for infringement of copyright and other forms of intellectual property, possibly without reciprocal guarantees to the vendor. These problems are not beyond the capability of the legal system to solve, but they do indicate that deployment of IVHS may sharpen the issue of the rights to intellectual property and the necessary safeguards for its licensees.

Also, consistent with their experience with traditional forms of contracting, some believe that if they procure equipment with government funds (even if those funds don't fully pay for the development cost of the equipment) they are entitled to a full license (or even ownership) of the related intellectual property; they believe that if software is developed or enhanced with public funds, an agency should not be forced to pay for it a second time.[101,102,103] One of their real concerns is that they will help pay for the development of intellectual property that can confer a monopoly on a private firm, thereby increasing their costs and reducing their flexibility in the future-being forced into a sole source procurement is one of the worst positions for a government agency.[104,105] This is especially true if the development work is done in response to generic specifications, and fully funded by govemment.[106] Some believe that they should have the right to transfer the intellectual property to other governments or agencies, and in some cases their procurement regulations support this view.[107,108]

Some agencies are more balanced in their views, suggesting that government might limit its share of intellectual property rights to those needed for the public portion of IVHS deployment, and possibly those additional rights that could help government recover its costs by licensing others.[109] The revenue might also be used to help support for profit public/private partnerships, or to encourage the development of IVHS products and/or services.[110,111] Ownership of patents might be shared among various governments and the vendor/developer, possibly negotiated on an individual project basis.[112,113] Agencies also want up front disclosure of a vendor's licensing practices for patents it intends to employ on government funded projects.[114] Others agree with private sector vendors that an open architecture would help to protect government agencies, if coupled with licensing agreements with patent holders.[115]

There is also the possibility of a coupling between protection of vendors against liability and against loss of their intellectual property; governments may be unlikely to offer liability protection in connection with a product, absent considerable knowledge of, experience with, and confidence in the product, based on full disclosure of the intellectual property.[116]

Federal government claims of intellectual property rights may also create problems.[117,118] For example, in a cooperative agreement with the State of New Jersey, FHWA claims a royalty free license to use copyrights and patents developed with federal government funds under the agreement for government purposes. For copyright, it is not clear from the agreement whether FHWA could sublicense any other transportation agency involved in IVHS to use the vendor's intellectual property-a license of such breadth could destroy the vendor's ability to sell its software or trade secrets to any other transportation agency. In some cases government procurement regulations even permit the government to transfer the license rights to competitors of the vendor that developed the intellectual property. For patents the license required is narrower, and probably would not embrace sublicensing to other transportation agencies, but the vendor is obligated to disclose inventions to the federal government and to apply for patents; thus it could not simply hold an invention unprotected as a trade secret.

The above summary suggests that the expectations of the public and private sectors are far apart on the matter of intellectual property, but it is the kind of issue that can be resolved by negotiation. FHWA may wish to consider organizing a forum including representation from various transportation agencies and private sector firms, to consider possible elements of a uniform, nationwide policy on intellectual property.

c. Antitrust Considerations

Certain business partnerships that have the potential to exert undue influence on the market and distort a competitive outcome are vulnerable to antitrust law. The need for a great degree of uniformity and standardization in IVHS technology and software requires major industry players to interact intensively at least through the standardization process, by means of such mechanisms as IVHS America. While such interaction ***per*** se does not raise the red flag of undue influence or collusion, firms involved in these types of processes need to be circumspect The IVHS community should recognize that the antitrust laws are not merely an inconvenience, but were enacted in response to past excesses that should not be allowed to recur, even if private investment in IVHS is thereby impeded. If the federal government exerts pressure for a common approach, and tries to bring all the major players under the same tent, there may be a clash between the need for cooperation and the strictures of antitrust law. It is important to explore this dynamic tension and to set out constructive policy options for both private business and government.

So far antitrust considerations have not emerged as major impediment to IVHS. Some believe that policymakers should concentrate first on creating a competitive market, by adopting an open architecture for IVHS, and should not encumber the ability of U.S. industry to deploy IVHS services and products, or to compete in the international marketplace, by overly restrictive antitrust enforcement.[119] They believe that joint ventures and teaming arrangements are necessary, given the scope of public and private investment required for IVHS[120], but believe that the National Cooperative Research Act of 1984, coupled with existing enforcement policies of the U.S. Department of Justice, offers adequate flexibility in this area.[121] One suggests that a safe harbor criterion be adopted, consistent with that adopted in the National Cooperative Research Act for research and development projects, providing antitrust protection to partnerships attracting less than 25 percent of the relevant market, but including safeguards to ensure that collusion does not occur in the early stages of development.[122] Others believe, without a great deal of elaboration, that antitrust issues are not a significant deterrent to IVHS,[123,124,125,126] and some assert that antitrust regulations should not be allowed to preclude such cooperation between manufacturers as may be necessary to ensure interoperability of different IVHS equipment.[127]

d. Communications Licenses

IVHS operational agencies are no less subject to the Communications Act than any other public or private agency. Thus these agencies face the possibility that the radio spectrum necessary to operate their IVHS apparatus could be restricted or eliminated at any time by the Federal Communications Commission (FCC). These agencies may seek to force the equipment or system vendor to assume the liability for FCC restrictions on or withdrawal of necessary spectrum, perhaps requiring that the vendor agree to modify the system to adapt it to different spectrum at its own expense.[128]

7. Technical Standards

It is widely understood that technical standards are a two edged sword, that both carves the rough edges off technological building blocks and thwarts innovation. Which side of the blade dominates in any set of circumstances defines the success or failure of entire industries. By standardizing too late, we may reap a chaotic market of marginally different but incompatible products; what could have been a strong and synergistic business or industry is instead weak and irrelevant. By standardizing too soon, we may foreclose innovative developments that could reduce costs, or even transform a plodding product. or service into a revolutionary one. We must make the best choice considering both the U.S. market (from the perspectives of both vendors and users) and the export market (from the perspectives of both vendors and the makers of U.S. economic and trade policy). Thus the tradeoff between standardization and innovation is difficult, and the stakes are high.

The effect of innovation on technology, and the related effect on costs, are closely related to technical standards and the basic tenet of capitalism: competition. Competition is the engine of capitalism, the basis of our economy. Competition drives the development of technological alternatives-without it we soon lapse into obsolescence. The diminishing of competition (e.g., through adoption of technical standards) is often seen by business as having a calming effect, as well as a positive effect on revenues, owing to the avoidance of risk; this is true only in the short term, for the passage from calm to obsolescence to irrelevance is all too predictable and all too rapid.

We cite the above truisms only to put into perspective the oft heard chant for standardization. Surely there are advantages to standardization-only a fool would argue that the width of railroad track is a proper subject for creativity and competition. Yet we should be skeptical of the clamor for standards, for its strongest advocates are sometimes more interested in a protected, short term market than in long term productivity.

In the IVHS arena, virtually all participants believe that technical standards will be necessary for successful development, but their views differ in the details. Some recognize the tradeoff between promoting compatibility and stifling innovation; there is concern that nonessential standards should be avoided.[129] Most groups believe that standards should be voluntary,[130] and should be developed by organizations presently involved in standards activities.[131] Standards organizations themselves[132,133], and those that aspire to that role,[134] are strong advocates of this view, but there are contrary views as well.[135] Some believe that the federal government should participate in standards activities.[136] Others would rely principally on market forces,[137,138] and suggest (approvingly) that de facto standards may develop.[139] There is support for open standards, designed to allow for multiple suppliers and alternative implementations. The degree to which standards should be international, national, regional or local should be considered carefully.[140,141,142,143,144,145] There may be good reasons for distinguishing between infrastructure standards and vehicle standards.[146,147]

Some believe that standards are needed at an early stage in IVHS development,[148,149,150,151,152,153] either generic (largely non-technical) or specifically for certain high priority elements (e.g., detection, surveillance and data management technology standards,

as well as communications standards and protocols);[154] others favor delaying final standards until a later stage in the development of IVHS.[155,156,157,158]

8. Safety

It goes virtually without saying that safety is of paramount concern when millions of vehicles, traveling at high speed, are entrusted to systems designed or operated by private businesses. Apart from the legal liabilities, no business could withstand the loss of reputation arising from significant safety related failures in a major infrastructure system. No business could afford to recall a nationwide traffic management system for a safety upgrade, and no business could afford not to do so if it becomes necessary. Safety is thus an important concern of business as well as government, and must be considered at every stage in the development of IVHS.

Some of the same electronic equipment that is under study to improve IVHS safety may also yield greater access to driving for the disabled.[159] If this proves to be true, it would yield a demonstrable social benefit that would be valuable in its own right, and could also help to sell the overall IVHS program.

9. Reliability

Reliability is obviously important in the design and construction of individual vehicles--this is a major topic of interest nearly every time an individual or a fleet owner purchases a vehicle. It is even more important in the design, construction and operation of a traffic infrastructure to which millions of vehicles are entrusted. Many consumers will forgive a power outage traceable to a violent storm, but few are so willing to excuse an outage in a telephone central office or a key traffic management center traceable to sloppy maintenance or a coffee spill into a computer system. Millions of citizens will come to rely on a central traffic management system, and it must fulfill that trust.

D. Private Sector Issues

1. Profitability of IVHS Services[160]

The entire concept of private sector investment in IVHS is founded on the presumption of profitability. To a businessman, prospective profit is the ***sine qua non*** of any new venture or commitment, requiring a cold-eyed assessment of the potential for both profit and risk; to a policymaker, it is the subject of a research project. Whatever our viewpoint, if we want to foster IVHS we have two choices:

- be very sure that IVHS services will be profitable; or
- get ready to pay for them out of tax dollars.

private sector firms will gladly help the government plan for IVHS, either to seek to influence government policy or to garner government study funds; but in the end they will only commit their own resources to IVHS if profits are in clear view. Thus private sector firms will if necessary protect themselves from losses by declining, at the last moment, to follow through with the investments they have been encouraging us all to believe in. The government's only protections for its IVHS program, given this predictable private sector behavior, are:

- to define the program to survive without private investment; or
- to desigh the program to limit the risk of private firms to a demonstrably acceptable level.

There are many subordinate issues. Profitability may differ across metropolitan areas, for reasons of population density, average or upper tier income levels, congestion, wage rates of IVHS construction workers, etc. Particular IVHS services may be more or less profitable than others. IVHS could develop as a niche service for businesses or the well-to-do, or as a lowest common denominator. service for everyone. The benefits of IVHS could be widespread, or could accrue mostly to the wealthy. These subordinate issues are not crucial to the success of IVHS, but they can certainly slow down its acceptance if they aren't treated thoroughly at an early stage of planning.

E. Consumer Issues

1. Consumer Demand for IVHS[161]

It is never difficult to achieve a minimal market for high technology services in our economy. There are usually early adopters of exciting new devices or services at virtually any price, and another layer of customers at more earthly price levels. For the would-be seller of gull wing sports cars or 35 inch TV sets, that is often enough.

IVHS is in another category entirely. The infrastructure cost of IVHS is high, and not much different. if it attracts ten million customers or just ten. Moreover, it could be argued that the government has no business, indeed should have no interest, in fostering a very costly initiative for the benefit of business or the wealthiest slice of the population at large. Nor will the private sector finance such a costly initiative if large numbers of customers cannot be forecast. Thus it is axiomatic that IVHS will not develop without clear and positive consumer demand. No controversy here. The only remaining issues are:

- Who will pay for the market studies?
- Who will believe them?
- Which specific services and market sectors appear most promising?

This concise summary of the need to identify and quantify demand should not be taken alone, as a dose of superficiality. There are obviously many important subordinate issues. Latent demand, once released, (at least for AVCS) might saturate the newly expanded roadway capacity. Elasticity of demand and the IVHS price structure could combine to alter drivers' choices of routes, trip schedules, vehicles, or even modes of transport, with both positive and negative results. And cross effects between economic and social factors could distort otherwise predictable market based behavior.

2. Consumer Attitudes Toward Pay-for-Use[162]

There is a strong trend toward pay-for-use, driven by a desire for economic efficiency or increased revenue, in many areas of our economy. In many parts of the country the telephone company charges for local calls using message units, with calls of longer duration or in some cases covering greater distances charged at a higher price; virtually all toll calls are charged on

the basis of time and distance. Cable television companies have been promoting pay-per-view service for special events and important films, and they see impulse pay-per-view as the long term holy grail of profits. Our Interstate highways are interrupted by toll highways, bridges and tunnels. Parking meters charge us for each 15 or 20 minute interval. It scarcely matters what service we require. The meter is always running.

Nobody ever asked the consumer. The advocates of economic efficiency and seekers of profit expect the consumer to pay per view, per mile, per minute, per bridge whenever asked. Maybe the consumers will continue to accept the automatic, surreptitious deductions from their bank accounts and credit accounts at every step in their busy lives (although the economic efficiency argument tends to break down when we are charged for something automatically when our attention is diverted). Then again, maybe the consumer won't. Then a lot of otherwise healthy businesses will very quickly find themselves in trouble. A lot of heavily capitalized tollways and IVHS may be underutilized.

It is wise not to assume business as usual in planning for IVHS by relying too heavily on routine market studies that tell us we can count on creeping incrementalism to justify our revenue projections. It is important to consider what would happen to IVHS if it were ever perceived by the public as an intolerable exaction among the increasing number of pay-as-you go requirements, especially if it were the last straw that breaks the camel's back.

F. Societal Issues

One of the essential tasks of government is to monitor and, if necessary, impose limitations on the non-economic activities of private businesses, termed externalities by economists. Thus, government requires proper disposal of toxic wastes, limits clear cutting of certain forests, prevents excessive development of wetlands, and mandates the inclusion and use of seat belts in automobiles and aircraft. IVHS raises a variety of such issues, as a result of both the technology itself and various mechanisms for implementing it. The private sector often will turn away from a potential profit opportunity if government forces it to confront spillover effects it imposes on society at large. This is as it should be when the overall costs to society, including the private firm exceed the benefits. However if government controls are perceived as being excessive, private firms, including those engaged in IVHS may shy away from pursuing a profit opportunity that is on balance both profitable and beneficial to society.

Another important societal issue is the extent to which the private sector will be required to provide universal access to IVHS, to rich and poor alike. This has become a major issue regarding the national information super highway. Early implementers of the national information super highway — cable, telephone, cellular and other providers of broad-band telecommunications networks — are targeting the most profitable and affluent markets first. There is a growing chorus within Congress that a condition of relaxing regulation and enhancing competition may be universal access to broad-band telecommunications. The requirement for universal access could have direct applicability to ATIS which will depend on a distributed network of databases. If the IVHS community only seeks the most profitable and affluent markets to the neglect of the poor, Congress might seek to block deployment until the poor and less profitable markets are served.

1. Privacy

A key issue for IVHS is its potential for intrusion into the personal privacy of individual citizens. Examples are the identification and tracking of individual vehicles, implying a capability for the identification of individual vehicle owners or occupants; the ability of a traffic management center to control the actions of a particular citizen; the potential for advance knowledge of the transportation plans of individuals obtained as a natural consequence of centralized assistance in ATIS assisted trip planning; etc.

The coupling of IVHS data bases and tracking capabilities with financial and other personal information about individuals greatly increases the potential for such intrusions. Centralized credit bureaus already contain vast amounts of personal data on virtually every citizen. It is not difficult to imagine the sale of location and tracking information to creditors or private investigators, enabling them to be ready and waiting for an individual citizen when he or she arrives at a destination. One can equally imagine that individual driver performance data, gathered for the purpose of forestalling accidents, could be transferred to others for commercial purposes. A driver's health insurance company might use such information to increase his insurance rates, or his employer might use it to influence his job assignments or his promotion potential.

It is easy to respond that such uses of IVHS capabilities will be forbidden. Much too easy. One need only recall the great controversy over the initial adoption of a national social security numbering system, in which similar issues were raised. ***The quid pro quo*** for congressional approval of the numbering system was an explicit prohibition on the use of social security numbers for other purposes. Now, many years later, these numbers are used on tax forms; on drivers' licenses; in every employer/employee relationship; and in every credit bureau record on every citizen. Government, for its own purposes and under continuing pressure from business, simply relaxed the legislated requirements whenever it became expedient, thus violating the social contract that it made with the public when the system was adopted.

Government needs to consider these issues for two reasons. On a general level, it is government's responsibility to help define the social environment of the nation, and privacy issues are an important element in that environment. More specifically, it is not obvious that citizens will accept continuing and accelerating intrusions into their remaining privacy; this issue is ripe for political exploitation. If significant numbers of citizens refuse to participate in IVHS operations, whether by refusing to buy the necessary equipment or by avoiding regions or roadways where IVHS is in operation, certain elements of IVHS may be unprofitable and could ultimately fail. Thus it is important to consider the need for IVHS implementation plans that could preclude, not simply forbid, excessive intrusions into individual privacy.

Giving serious attention to privacy, both as a societal good and as a potential barrier to IVHS, should not preclude giving equal time to the benefits of IVHS applications that require the use of personal data. It is not difficult to find potentially important applications. The key point is to avoid involuntary intrusions, or theoretically voluntary intrusions that are the ***quid pro quo*** for virtually essential needs (e.g., a driver's license or auto insurance), or a continuing series of incremental intrusions, each just below the threshold of pain, that in me aggregate could reduce privacy to a historical anachronism.

Difficult issues abound.[163] Is privacy more important than automated traffic law enforcement? Do we sacrifice the personal privacy of millions of-citizens to make it easier to trace stolen vehicles? To catch a few speeders? To make it easier to collect parking fines from a scofflaw? Do we require a permanent on-board record of every mile driven by every citizen, just to reduce occasional fraud in the sale of used cars? How much law enforcement do we really need, and how much are we prepared to pay for it, in both dollars and other societal costs such as privacy? Would we continue to tolerate every one of our existing laws if detection and punishment of every infraction, however minor, were an absolute certainty?

How do we balance privacy concerns in the collection of user fees? Do we really need a personalized smart card for payment of tolls, or could we use an anonymous debit card similar to the Japanese telephone card or the Washington DC Metro card, which store prepaid value without identifying the owner? Do we need permanent identification of millions of individuals and vehicles just to improve the efficiency of collection of a 75 cent toll? Should the public be given a clear description of these implications before IVHS is approved by the Congress?

Many people who have not thought a good deal about privacy issues respond to the effect, "So what? I don't have anything to hide!" And of course they don't. Most people don't have anything to hide. Information of an inherently private nature, if not misused, causes no harm. But our entire system of government, from the Constitution down to the most minor legislation, is designed to protect citizens from the misuse of government power, whether inadvertent or malevolent. Consider a "worst case" scenario, similar to what nearly happened recently in Russia: a truly despotic individual manages to become elected president, and seeks to use a centralized data base of private information and an associated surveillance system as a mechanism to control the populace. Such a mechanism, supported by modem computer technology, would be so powerful a means of control that its user might never be dislodged.

Some would consider this line of discourse to be truly alarmist, and the case for or against it should not be made here. Our purpose is merely to identify for further analysis and public discussion an issue that could have potentially far reaching consequences, and that is exacerbated by some of the technologies and plans being considered for IVHS.

The IVHS community generally sees privacy considerations from its own special viewpoint: accepting the benefits of IVHS and assuming that the public at large will ultimately see them too. The community reasons that the public will "go along" as soon as the benefits are explained, and will be willing to "give up" a measure of personal privacy to achieve these benefits.

And so it might. Although the benefits of IVHS are significant, and in many cases long term, they are nonetheless real. Improved efficiency, increased speed of travel, and potential reductions in pollution are all desirable public (and individual) objectives.

But what about the related issue of law enforcement? This is the province of a related public agency, virtually inseparable in the public mind from the agency that collects tolls or displays traffic instructions-in any event, the two agencies cooperate closely. Add video cameras, vehicle IDs, magnetic stripes on drivers' licenses, and the propensity of auto insurers to capture all sorts of data, and the motorist may well feel intimidated. The problems with legislative approval for "photocop" enforcement of toll violations and the closely related issue of the use of

the same video images for other law enforcement purposes (e.g., speeding tickets by mail) may be just the early manifestations of public concern about privacy.

A couple of distinctions need to be made here. One need not have criminal intent to be concerned about government access to personal data. Also, it is all too easy to transfer dissatisfaction with the traffic laws, or with the structure and operating methods of the insurance industry, to the personal dam collection or surveillance methods that could be used to foster them. Yet modern data collection, storage and retrieval systems are so much more powerful than those available in even the recent past that they create a sea-change in the relationship between increasingly powerful government and private sector entities and increasingly powerless individual citizens. This process is widespread, and not at all confined to IVHS, although the enhanced surveillance capabilities of IVHS technology could greatly extend the reach of these systems. Thus IVHS proposals may crystallize public opinion on these broader issues, and policymakers will need to consider them from a broad perspective.

It is useful to distinguish between two categories of privacy issues: information privacy issues (concerned with historical information, or "where someone has been" and surveillance issues, or "where someone is or is going." The former can in principle be resolved by restrictions on the storage or use of the information, while the latter raises "significant fourth amendment concerns" that are more difficult to resolve. When law enforcement uses are involved, the problem becomes more difficult still-although the information may aid in crime prevention and investigation, legal restrictions and good public policy may limit such uses.[164]

Some transportation agencies have already faced the privacy issue. A few have confronted public opposition on privacy grounds, notably in regard to the "photocop" issue, which has transferred acute public concerns about "ticket by mail" to the less controversial matter of toll evasion.[165,166,167] Some believe that the threat of loss of privacy could "seriously hamper" IVHS acceptance by the public and business, that "perceived and real threats to privacy must be identified," and that "adequate safeguards" should be adopted now.[168] Others believe that IVHS should be deployed in a way that "protects individual privacy," with mandated "complete disclosure" (including "how...data will be used, and how identities will be protected"), and requiring that ". ..data on travel patterns of individuals should be protected by the recording agency, and used only for billing purposes,"[169] or otherwise keep individual identification to an "absolute minimum," except where the specific user sees a "real benefit" and authorizes the intrusion.[170] Some believe that "it would be advantageous to develop procedures ensuring privacy,"[171] perhaps by means of federal legislation.[172] And some believe that, although it cannot be decided now, the privacy issue must be faced squarely, focusing on the particular circumstances that create concern, and making it clear to the public that these issues will be resolved as IVHS develops.[173]

Some agencies are broadly confident that privacy will not be a major issue for IVHS, especially if the user sees a cost advantage or other benefit;[174,175] one agency reports user comments that "We're being watched now anyway, what's the difference?" but nonetheless has adopted a "policy decision that customer records will receive the greatest degree of confidentiality possible" and in any event plans to continue to offer the opportunity for payment in cash.[176] Some believe that privacy considerations should be ignored, one stating that "There will be a certain amount of backlash, but (the) majority of (the) public will come around. Even if they

don't, we should move ahead."[177] Another believes that "the privacy issue is moot" because police already use the "common vehicle license plate" for tracking and surveillance.[178]

A number of agencies regard privacy as essentially a public education matter, believing that privacy "could be a concern if the public is not educated on the benefits of IVHS technologies," sometimes drawing a distinction between IVHS and the automated law enforcement techniques that have drawn public opposition.[179,180]

One agency advocates a public education campaign, but asserts that "we have not promoted our surveillance and detection future plans...(nor) invested heavily into video cameras or overhead detection systems that travelers can see as they drive, but we plan to in the future." This agency also states that it has "concentrated on focusing toward the benefits we plan to provide to the motorists."[181] The benefits of IVHS are substantial, but the public could come to view such an educational campaign as deceptive, perhaps resulting in a greater "backlash" than might occur if the campaign had not been mounted. If the IVHS community engages in a public education campaign, it would be highly desirable to make it as straightforward as possible.

One key IVHS participant, a manufacturer, dismisses privacy concerns by characterizing driving as a "public event," and argues that there is no "reasonable expectation of privacy" associated with it.[182]

There is also support for engaging business and public users in the process of developing privacy safeguards,[183] perhaps in the course of development of technical standards.[184]

What conclusions might be drawn from these agency views and early expressions of public sentiment? First, it seems risky to conclude that an ever docile public will continue to accept any proposals that compromise personal privacy, to gain "benefits" that appear costly, long term, and difficult to understand. We must recognize that the issue of privacy is not simply an "education" problem-it is a key element in the broad policy tradeoff that will be necessary to gain public ***(i.e.*** legislative) approval for IVHS. Proponents of IVHS may need to swallow hard and yield the battle of privacy protection to win the war of approval for the program itself. Second, it may be desirable to make a sharp distinction between the use of IVHS technology as an enhancement of the nation's transportation system and as a tool for law enforcement-it may be necessary to "give up" the law enforcement applications of these new technologies to gain public approval of the transportation benefits.

Policymakers could also consider an alternative architecture for IVHS that does not depend upon technologies or systems that are inherently intrusive. To fail to do so might leave the IVHS community with essentially no options if the future public debate generates strong opposition on privacy grounds. It would be prudent to have at least a "backup" plan that does not depend on tracking of identified vehicles, or on relationships to financial records of individual citizens, or on unification of transportation and law enforcement. Such a plan might yield fewer opportunities for the marketing of personal data, and might force the law enforcement community to seek its own initiatives independently, on their own merits, but might greatly improve the prospects for a transportation-oriented IVHS program.

At a minimum, IVHS policymakers should recognize that the public will ultimately be educated on all of the arguments for and against IVHS, before the program is adopted. This

education process will include both the arguments of the IVHS community and those of others, including the advocates of privacy protection. Thus it will be important to avoid the "we're your government and we're here to help you" mode of discourse.

2. Pollution

National, state and even local governments have developed a broad array of laws and regulations intended to protect the environment. Considerable progress has been made to conserve and safeguard the nation's natural resources. These laws and regulations, however, pose an increasing challenge to achieving greater mobility through improvements in highway transportation, including IVHS .

For the most part, improvements in the environment and in mobility are not incompatible. Usually undesirable release of waste into the environment is an indication that the societal choices in pursuing mobility are less than optimal. IVHS, the application of advanced technology to enhancing mobility, is one innovative approach to managing transport that could yield reductions in emissions.

Many in the environmental protection movement question the desirability of improved highway transport. They believe IVHS is principally intended to increase highway capacity. They contend that application of advanced technology may well improve accessibility and reduce congestion, but that it will also induce travel: directly and immediately by reducing travel time, and indirectly by improving accessibility and thus stimulating long term economic development. They argue that the combined effect of reduced congestion and greater economic activity will be more traffic. They believe that highway improvements brought about by any means, including advanced technology, are self defeating and damaging to the environment because of increased pollution and conversion of natural resources, especially undeveloped land, to commercial uses. Many environmentalists prefer instead to allow congestion to build on highways, thus changing the travel impedances of highway travel relative to mass transit, walking, bicycling, ***etc.*** and thereby encouraging non-highway travel.

Some environmental advocates may use mediation (at best) and the courts (at worst) to try to win their point of view. Some may simply seek full compliance with environmental laws, and thus bring great pressure upon responsible public agencies, federal, state, regional and local, to toe the line. The more extreme may use the laws and the regulatory process to obstruct or delay deployment as much as possible. This description of possible tactics used against IVHS is not meant to denigrate those most opposed to IVHS on environmental grounds, but only to clarify one potential barrier to deployment.

The 1990 Amendment to the Clean Air Act has become the most overriding environmental concern affecting transportation in metropolitan areas not in compliance with National Ambient Air Quality Standards. The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) reinforces the importance of the 1990 Amendment to the Clean Air Act. ISTEA sets up a Congestion Management and Air Quality Program that requires that congestion management actions in non-attainment regions not result in increases in air pollution. The Interstate Maintenance Program also precludes federal expenditures from this pot of money on the Interstate if more lanes were added. Most important is that long range transportation plans, Transportation Improvement Programs (TIP) containing regionally significant transportation projects, and the

projects themselves, including ATMS and ATIS must be in conformity with State Implementation Plans for attainment and maintenance of national ambient air quality standards.[185]

Among the projects that will undoubtedly be financed with federal funds, and included in an MPO's TIP, will be major ATMS and ATIS projects. The National Environmental Policy Act requires that an environmental impact statement be prepared for these projects. In addition, many fail to appreciate, or even ignore, NEPA's requirement that an environmental impact statement be prepared for TIPs. Under Council on Environmental Quality Guidelines for the Implementation of NEPA, which has the force of law, an EIS must be prepared for any program (i.e., a program of projects) receiving federal funds and expected to have a major impact on the environment. Environmental groups seeking strict compliance with NEPA can use the courts to force MPOs to prepare programmatic environmental impact statements and delay the undertaking of IVHS and other projects included in a transportation improvement program until a draft EIS has been completed, presented in a public hearing, and finalized.

This is by no means all bad. Sensible programming decisions by MPOs and the jurisdictions within them require careful analysis of the pros and cons of each project contained in the TIP, including air quality impacts and other social, economic and environmental effects. For IVHS projects to warrant a high priority, their benefits must be greater, relative to their costs, than other transportation actions, whether they be demand management measures, new highway construction, new bicycle facilities, or mass transit improvements.

A major barrier to the deployment of IVHS is the inability to articulate its benefits. If IVHS projects will in fact result not only in reduced congestion, but also in reduced air pollution, energy consumption, and so on, someone has to do the analysis to document these results. An environmental impact statement is an excellent vehicle for performing the analysis. The analysis should at the minimum be performed at the program level, because that is where funding decisions are made. Project level environmental impact statements are also warranted. However, by using the tiering process described in the CEQ implementation guidelines, considerable savings can be achieved in project level analysis by focusing first on program level analysis.

A closely related issue is the need to identify the source of funding and staff resources to perform this complex analysis. Few MPOs are currently equipped to perform programmatic environmental analysis that includes a detailed analysis of ATMS and ATIS projects, particularly air quality impacts.

A flaw in the posture of IVHS advocates is that, while there have been efforts to make IVHS broad-based, and thus reflect highway and transit as well as urban and rural interests, it is still not neutral with respect to all modes. There is no "Advanced Bicycle Transport System (ABTS)," or "Advanced Pedestrian Transport System (APTS)." Many environmental advocates depend on walking, bicycling and bus transportation more than on the auto. Until non-auto users are convinced that technology can benefit their travel choices and preferred lifestyles, many of them will strongly oppose IVHS.

Income inequality between users and non-users of automobiles is another institutional factor that affects environmental politics. It is well known that auto ownership is highly correlated with income. If IVHS primarily benefits auto users, taxation to support IVHS may be regressive. Those who prefer to let congestion build up would argue for a more equitable approach: let the price

people pay to use the highway system be exacted in travel time, not taxes. Everyone, regardless of income, has a time budget of exactly 24 hours per day. Smolenski and others, in a little noticed article written in the early 1970s, make exactly this point: using congestion to ration scarce highway facilities is politically preferable to taxation.[186] The only flaw in this argument is that if congestion builds to the point where it stifles economic activity, and the poor or lower income earners are disproportionately affected, their loss in income may be greater than the cost of regressive taxation to finance IVHS.

It is likely that IVHS will, on balance, yield a net reduction in the total amount of pollution created by vehicular traffic. But the increased highway efficiency made possible by IVHS, the consequent avoidance of construction of new highways, and stronger land use controls that foster high density development could increase traffic of existing highways; this could lead to increased concentrations of pollution along existing transportation corridors.

The key issue is whether increased emissions associated with induced travel will offset reductions in emissions achieved by ATMS or ATIS. Whether emissions of a pollutant will increase is partly a function of the operating speed of vehicles and the change in operating speed brought about by ATMS or ATIS. It is well known that hydrocarbon and carbon monoxide emissions tend to decline and nitrogen oxide emissions tend to increase as speed increases. Note that in a particular metropolitan area, pollution reduction objectives will vary with respect to volatile organic compounds, carbon monoxide and nitrogen oxides depending upon which pollutants are relevant to attaining or maintaining national ambient air quality standards.

Induced demand may very well be significant if a highway improvement involves a very large improvement in accessibility, such as a new freeway that provides a new connection between population centers. AVCS that results in platooning of vehicles and effectively doubles or triples capacity is likely to have this effect. But ATMS and ATIS is projected to result in perhaps only a 10 to 20 percent increase in effective capacity on existing facilities, and a comparable reduction in travel time. Induced travel is unlikely to be greater in percentage terms if ATMS and ATIS are applied throughout a region. If ATMS or ATIS were applied to specific corridors or main routes, route diversion could be significant.

3. Distributional Issues

Distributional issues go to the heart of democracy. Although these issues arise in virtually every program involving government funds, some are unique to IVHS.

One set of distributional issues arises from the dependence of IVHS on substantial participation from the private sector as a partner in its deployment. It should be no surprise that business seeks out high profit opportunities and avoids low profit or risky ones. It is virtually certain that the best business opportunities will arise in densely populated metropolitan areas, where equipment and facilities can be used efficiently and customers are everywhere. Thus rural areas may be the last to be served, even though these areas would also benefit from IVHS, particularly ATIS technology.

Another distributional imbalance, again having its greatest impact in rural areas, is the need of IVHS for various enabling technologies (e.g., telecommunications facilities). It is again no

secret that telecommunications facilities are concentrated in densely populated areas, for reasons quite similar to those influencing the deployment of IVHS.[187]

Thus the cost-effectiveness of IVHS in rural areas is affected both on the demand side (a shortage of customers) and on the supply side (a shortage of necessary facilities). Only government intervention (e.g., by introducing financial incentives) will be likely to change this kind of distributional inequity.

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