I. 1. ITS: A SHORT HISTORY AND A PERSPECTIVE ON THE FUTURE[1]

1. INTRODUCTION

An article[2] on the development of Intelligent Transportation Systems (ITS) in this 50-year anniversary of the *Transportation Quarterly* and the 75th anniversary of the Eno Foundation is particularly appropriate. William Phelps Eno can in many ways be viewed as the great-grandfather of ITS. Eno's work in traffic control in the early days of highway transportation set the stage for the use of today's modern technologies in addressing the same issues with which he was concerned: congestion reduction and safety. I am honored to present this paper in this noteworthy issue of *Transportation Quarterly*.

This article describes the dynamic but short history of Intelligent Transportation Systems (ITS). ITS combines high technology and improvements in information systems, communication, sensors, and advanced mathematical methods with the conventional world of surface transportation infrastructure. In addition to technological and systems issues, there are a variety of institutional issues that must be carefully addressed. Substantial leadership will be required to implement ITS as an integrator of transportation, communications and intermodalism on a regional scale.

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[1] Reprinted with permission of the Eno Foundation. Sussman, Joseph M., "ITS: A Short History and a Perspective on the Future", *Transportation Quarterly*, (Special Issue on the occasion of the 75th Anniversary of the Eno Foundation), Eno Transportation Foundation, Inc., Lansdowne, VA, p. 115-125, December 1996.

[2] Parts of this article are drawn from, "Strategic Plan for IVHS in the United States", Report No.: IVHS-AMER-92-3, Prepared by IVHS AMERICA, May 20, 1992. The author was a member of the core writing team that produced that document.

2. HISTORY AND BACKGROUND

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

First, the group was looking ahead to 1991 when a new federal transportation bill was scheduled to be enacted. It was envisioned that this 1991 transportation bill would be the first one in the post-Interstate era. The Interstate System, a $130 billion program, had been the centerpiece of the highway program in the United States since the mid-1950s. By 1991 this project would be largely complete. A new vision for the transportation system in the United States needed to be developed.

While the Interstate had had a major and largely positive impact in providing unprecedented mobility at a national level, transportation problems remained. From the perspective of 1986, highway traffic delays were substantial and growing. Rush-hour conditions in many metropolitan areas often extended throughout the day. Further, safety problems abounded, particularly highway safety.

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

Two more major motivations for considering the future of surface transportation were national productivity and international competitiveness, both closely linked to the efficiency of our transportation system. In 1986, our major economic rivals in western Europe (Project Prometheus) and Japan (Project AMTICS and RACS) were advancing very quickly in developing new technologies for use in advanced surface transportation systems. Their use of high technology concepts in the information systems and communications areas were seen as the opportunities to revolutionize the world of surface transportation. This would improve the competitiveness of these nations and provide them with an important new set of industries and markets.

Further, it was recognized that these congestion, safety, environmental and productivity issues would have to be addressed largely by means other than simply constructing additional conventional highways. Particularly in urban areas, the economic, social and political costs of doing so were becoming too high.

Thus, in 1986, this small, informal group saw before it an opportunity and a challenge based on:

- new transportation legislation (at that time five years in the future),

- concern for continuing transportation problems in the United States despite major investment in the transportation system,
- the development by our economic competitors in western Europe and Japan of various technologies that could enhance their industry posture and their productivity, and
- future limits on conventional highway construction, particularly in urban areas.

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

What was envisioned and what came to be called Intelligent Vehicle Highway Systems (IVHS) and eventually Intelligent Transportation Systems (ITS), is but another example of the marriage of transportation and technology as a phenomenon that has existed throughout human history. In the early part of this century, innovation in construction and manufacturing technologies made the current transportation system possible.

We now have the need for a new round of technological innovation, appropriate to the transportation issues of today. For example, there are the "ITS-4" technologies. These technologies deal with:

1. the ability to *sense* the presence and identity of vehicles or shipments in real-time on the infrastructure through roadside devices or Global Positioning Systems (GPS);
2. the ability to *communicate* (i.e., transmit) large amounts of information more cheaply and reliably;
3. the ability to *process* large amounts of information through advanced information technology; and
4. the ability to use this information properly and in real-time in order to achieve better transportation network operations.

We use *algorithms* and *mathematical methods* to develop strategies for network control. These technologies allow us to think about an infrastructure/vehicle *system*, rather than independent components.

The small, informal group described above became "Mobility 2000", which produced a landmark document in 1990[3], laying out a vision for ITS.

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

In 1990, the need for a permanent organization became clear and IVHS America (the Intelligent Vehicle Highway Society of America) was formed as a federal advisory committee for the U.S. Department of Transportation.

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

As was envisioned in 1986, ITS was an integral part of ISTEA, with $660 million allocated for research, development and operational tests. Additional federal, state, local and private-sector funds were added to this initial allocation, leading to a substantial program.

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

The vision for ITS was articulated as:

- A national system that operates consistently and efficiently across the United States to promote the safe, orderly and expeditious movement of people and freight. Here, recognition of the need to think intermodally and about the needs for *both* personal and freight mobility was explicit.
- An efficient public transportation system that interacts smoothly with improved highway operations. The concept that ITS had to do more than simply improve single-occupancy-vehicle level-of-service on highways is captured here.
- A vigorous U.S. ITS industry supplying both domestic and international needs. The plan noted that the U.S. market for ITS hardware and software services would be on the order of $230 billion over the next 20 years. Extrapolating this internationally, it is not unreasonable to think about a $1 trillion international market in ITS over that time period, well worth the effort for the private sector to pursue.

The strategic plan talked about a vision for ITS, the mission for the ITS community, and the setting in which ITS would be deployed. It addressed strengths, weaknesses, opportunities and threats to developing and deploying ITS in the United States. Specific goals and objectives, as well as a formal plan for research, development, testing and deployment were outlined in the plan. This detailed plan included a discussion of the fundamental approach to ITS, the research and development necessary to reach the deployment stage, systems integration, and estimates of funding needed for the program.

The plan focused on three facets: First, *technology*, the development and integration of technologies that would allow ITS to proceed. Second, *systems*, the integration of technologies into systems for operating ITS. Third, *institutions*, the challenges that face the ITS community in developing the public-private partnership and the government interactions that would have to be developed at various levels. This third facet also addressed the educational challenge that the community faces and the organizational changes that would be necessary to have success in the ITS theater. It was recognized that while technology and systems were important issues in the development of ITS, the many institutional and organizational issues would be as complex and as difficult.

In the Strategic Plan, the recognition of *the transportation/ information infrastructure* was an important conceptual breakthrough. In other words, it accepted an intermingling of the new technologies in computers, communications and sensors, with conventional infrastructure to create something wholly new in the world of transportation. In thinking about the development of this concept, it is helpful to use a construct developed by one of the seminal thinkers in management, Peter Drucker. He talks about three revolutions that have occurred in the last 200 years: the industrial revolution, the productivity revolution and the management revolution. In the industrial revolution, roughly 200 years ago, new technology replaced manpower with machine power, with extraordinary improvements in capacity.

About 100 years ago, we experienced the productivity revolution. This involved applying *knowledge to work.* It included such concepts as the assembly line and ideas in scientific management developed by Frederick Taylor. This productivity revolution has given rise to extraordinary improvements in productivity (about 4.5% annually over a long time period) and great improvements in quality of life. However, Drucker argues that this revolution is largely over. It applies mainly to improving the productivity of manual workers, who, in the developed world of 1950, represented about half the workers. In 1990, only about 20% of the workers, and in 2010, perhaps 10% of the workers are, or will be, manual laborers. There is only modest leverage left here.

Drucker argues that what is needed is a new revolution he calls the management revolution which is the idea of applying *knowledge* not to work but *to knowledge*. This will allow us to greatly enhance the productivity of non-manual workers. It can also be a mechanism for creating wealth and quality of life at a level we have been unable to achieve through the industrial and productivity revolutions over the last 200 years.

ITS is part of this management revolution. A systemic approach linking vehicles and infrastructure is something fundamentally new in transportation.

It is convenient to think of ITS in terms of six areas: Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), Advanced Vehicle Control Systems (AVCS), Commercial Vehicle Operations (CVO), Advanced Public Transportation Systems (APTS), and Advanced Rural Transportation Systems (ARTS).

3. FUNCTIONAL AREAS IN ITS

3.1 Advanced Traffic Management Systems (ATMS)

ATMS will integrate the management of various roadway functions. It will predict traffic congestion and provide alternative routing instructions to vehicles over regional areas to improve the efficiency of the highway network and maintain priorities for high-occupancy vehicles. Real-time data will be collected, utilized and disseminated by ATMS and will further alert transit operators of alternative routes to improve transit operations. Dynamic traffic control systems will respond in real-time to changing conditions across different jurisdictions (i.e., by routing drivers around accidents). Incident detection will be a critical function in reducing congestion on the nation's highways.

3.2 Advanced Traveler Information Systems (ATIS)

ATIS will provide data to travelers in their vehicles, in their homes or at their places of work. Information will include: location of incidents, weather problems, road conditions, optimal routings, lane restrictions, and in-vehicle signing. Information can be provided both to drivers and to transit users and even to people before a trip to help them decide what mode they should use.

3.3 Advanced Vehicle Control Systems (AVCS)

AVCS is viewed as an enhancement of the driver's control of the vehicle to make travel both safer and more efficient. AVCS includes a broad range of concepts that will become operational on different time scales.

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

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

ATMS and ATIS will have early applications in urban and suburban areas. AVCS, particularly the Automated Highway System (AHS), is envisioned as a longer-term program. In addition, CVO, APTS and ARTS are three major applications areas that are already beginning to draw on ITS technologies.

3.4 Commercial Vehicle Operations (CVO)

In CVO, the private operators of trucks, vans and taxis have already begun to adopt ITS technologies to improve the productivity of their fleets and the efficiency of their operations. This is proving to be a leading-edge application because of direct, bottom-line advantages.

3.5 Advanced Public Transportation Systems (APTS)

APTS can use the above technologies to greatly enhance the accessibility of information to users of public transportation as well as to improve scheduling of public transportation vehicles and the utilization of bus fleets.

3.6 Advanced Rural Transportation Systems (ARTS)

The special economic constraints of relatively low-density roads and the question of how ITS technologies can be applied in this environment are challenges that are being undertaken by many rural states.

4. A BROAD APPROACH

ITS represents a broad systemic approach to transportation. ATMS represents overall network management. ATIS is the provision of information to travelers. AVCS is a new level of control technology applied to vehicles and infrastructure. Applications in urban and rural areas, involving public transportation, commercial vehicles and personal highway vehicles, are encompassed by ITS.

There are important technological issues to be considered, many involving the *integration* of various hardware and software concepts on a "real-world" transportation network. Few technological "breakthroughs" (with the likely exception of AHS) will be needed.

5. INSTITUTIONAL ISSUES

Of equal importance to technological and systems issues are various *institutional* issues that must be addressed if ITS is to be successfully deployed. Several are discussed below.

5.1 Public-Private Partnerships

A primary issue is the need for public-private partnerships for ITS deployment. One can contrast ITS with the Interstate System, the major transportation program in this nation in the 20th century. The Interstate System could be characterized as a public works system. The funding was provided exclusively by the public sector and the fundamental decisions about the deployment of the Interstate System were made by the public sector.

ITS, on the other hand, will require deployment of infrastructure, largely by the public sector, and in-vehicle equipment by the private sector. Therefore, ITS can be characterized as both a *public works and* a *consumer product* system. This will require unprecedented levels of cooperation between the public and private sectors if ITS is to work effectively as a national "seamless" system. The hardware and software in the infrastructure must be compatible with the hardware and software in the privately-acquired in-vehicle equipment.

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

5.2 Organizational Change

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

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

This is a fundamental shift for these public organizations. They will have to make a difficult transition over the next several decades for ITS to be successfully deployed around this nation, as will private-sector organizations that have supported the historical mission. A whole new set of professionals will need to be attracted to these public-sector organizations and related private-sector organizations. In addition, fundamental changes in the mission of these organizations must come about.

It is interesting to observe that on the Central Artery/Tunnel program in Boston, Massachusetts, one of the last major projects of the Interstate System, ITS is playing a major role. The contractor on the project is putting considerable resources into understanding and developing ITS systems that can be used in conjunction with the development of conventional infrastructure to make sure this mammoth ($10 billion) megaproject will, in fact, work. Together with the Commonwealth of Massachusetts, the Massachusetts Institute of Technology and MIT's Lincoln Lab, the contractor is working on traffic control centers, algorithms for effective routing of traffic, and roadside infrastructure that will permit efficient monitoring of traffic and incident detection.

The symbolism is strong. One of the great international construction consortiums working on the last of the great Interstate projects in this country is focusing on ITS technology to enable the finished project to operate effectively.

5.3 Academia in Transportation

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

The most important function of academia is the development of educational programs and the education of transportation professionals. The deployment of ITS implies change for transportation organizations. Consequently, a broader education of the transportation professional, including areas such as software systems, communications, a variety of systems analysis and operations research methodologies, information systems, and institutional studies will be required. What is needed is a "new synthesis" as an educational model for the "new transportation professional".[4] The development of that synthesis and the education of the new transportation professional will be a critical contribution by the academic community.

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

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

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

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

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[4] Sussman, Joseph M., "Educating the 'New Transportation Professional,'" *ITS Quarterly*, ITS America, Washington, DC, Summer 1995. N.B. This article appears in Section III of this volume.

triad in an effective way, research universities have a unique role to play in the ITS arena.

6. TRANSPORTATION AND CHANGE

The linking of conventional infrastructure with the technologies of information systems, communications, sensors and advanced mathematical methods for the movement of both people and freight is an extraordinary development. We cannot begin to foresee the changes (possibly both positive and negative) that will result from the development of this transportation/information infrastructure.

Think, for example, about the changes that came about as a result of the Interstate System, a $130 billion program, starting in 1956. The Interstate program can be thought of as an expansion, *in-kind*, of a conventional highway system. Granted, the Interstate was a substantial expansion in capacity and network size, but it was an in-kind improvement nonetheless. Yet, we had a hard time predicting what would happen as a result of this implementation. For example:

- The inter-city trucking industry was formed, and a financial blow was dealt to the railroad industry, as it lost substantial market in high-value freight. This led, in turn, to a fundamental redefinition of the relationship between the public and private sectors in the freight industry in 1980, through substantial deregulation.
- The Interstate led to an unprecedented and unequaled mobility between and into U.S. cities and gave rise to the regional transportation concept, with wholly new methods of planning being required for region-wide analysis and design.
- The Interstate System included the development of circumferential belts around major cities, leading to development patterns quite at variance with the ability of public transportation to service it and, as described by authors such as Joel Garreau, the development of "edge cities", a fundamentally new kind of urban structure.
- The Interstate led to a fueling of the post-war economic expansion and a period of unprecedented prosperity in the United States.
- A "stop the highway" backlash in urban areas resulted from the Interstate, and a political polarization between the build vs. no-build factions became a fact of political life in U.S. transportation.

All of this results from an expansion, *in-kind*, of the highway system.

Regarding ITS, we have already seen:

- the reinvention of logistics through supply chain management, linking inventory management and transportation in wholly new ways;

- dramatic moves into surface transportation by organizations not traditionally involved, such as the national labs and aerospace companies in the United States;
- changes to academia, with new alliances and new academic programs beginning to form and faculty participating in transportation education and research who have never been part of that process before; and
- the building of new relationships among public-sector agencies to enable regional and corridor-level system deployment.

These have already happened, and it is just the beginning. We cannot begin to foresee all that will occur. The enabling technology of ITS, the transportation/information infrastructure, can and will have profound effects. We hope they will be positive -- accessibility, economic growth, improved quality of life, improved information for planning and intermodal transport. However, unforeseen outcomes, both positive and negative, are certain with this new transportation enterprise.

We need to think broadly about ITS and the transportation/information infrastructure. Our job is the mobility of people and goods and, in fact, knowledge, as Peter Drucker would put it. ITS is an enabling technology to permit us to do great things in these areas. We cannot foresee all the possibilities of ITS -- all its potentials and all its pitfalls. Still, it is certainly the most exciting development in transportation in many years. We, as transportation professionals, need to make it work.

7. THE POST-STRATEGIC PLAN PERIOD

The years since the Strategic Plan have been busy ones in the ITS community. Program plans which translate the Strategic Plan into specific shorter-term actions have been developed. A national ITS system architecture has been developed. The U.S. DOT has established the Joint Program Office as a group that cuts across the modal administrations of DOT to address ITS research, development, testing and deployment. ITS America continues to grow, with 1,000 members in 1996, and more than 3,000 people at the most recent ITS annual meeting in Houston, Texas. The international community in ITS is cooperating at a professional level with the ITS World Congress, initiated in Paris in 1994, continued in Yokohama in 1995, and being hosted in the United States in Orlando, Florida, in 1996.

Space does not permit documenting all the ITS successes to date. To name but several: One can look at TRANSCOM in the congested New York/New Jersey/Connecticut region for an example of an ITS deployment providing ATMS, ATIS and electronic toll collection in the tri-state area. The SmarTraveler program in Boston is an example of an advanced traveler information system with a strong initial track record. The Houston public transportation system is yet another example of an ITS deployment which is quantitatively and qualitatively changing the supply of transportation service in the Houston metropolitan area. Various deployments in Western Europe and Japan are advancing as well.

In 1996, at the Transportation Research Board Annual Meeting in Washington, Secretary of Transportation Federico Peña announced the Intelligent Transportation Infrastructure (ITI) and Operation Timesaver, with ambitious goals for deploying ITS technologies throughout the country by early in the 21st century.

Private-sector organizations have continued active programs in ITS. The automobile manufacturers in the United States and abroad are marketing advanced traveler information systems, supported by major initiatives in communications and in computerized mapping.

Cooperation between various public-sector agencies also characterizes the ITS movement. Commercial vehicle operation initiatives, such as HELP and Advantage I-75, involve many public jurisdictions as well as private-sector truckers. The I-95 coalition cooperates on ITS technologies stretching from New England to Virginia.

Efforts to make ITS truly intermodal, both for travelers and freight, are underway. For example, exploiting ITS to enhance truck-rail-ocean freight intermodalism is high on the agenda.

ITS technologies and concepts have begun to be embedded within the transportation system. The benefits of such technologies are being established through the collection of field data that supports the claims of congestion reduction and safety enhancement. A new round of advances and deployments is imminent.

The reauthorization of ISTEA, the 1991 federal legislation that first enabled the ITS program, scheduled for 1997, will be a major milestone. This should happen as the ITS community anticipates its major role within this legislation to move to the next level of system deployment.

8. CONCLUSION

The focus for ITS in the future is clearly on deployment. Taking research and operational test results and putting them into routine practice is the emphasis in the ITS world today.

How to best advance the deployment agenda is currently a matter of intense discussion in the ITS community.

The best approach is for ITS to focus on regions as critical units of economic competition.[5] Often, we speak of the "competitive region". The work of Professors Michael Porter and Rosabeth Moss Kanter at the Harvard Business School emphasizes the idea that subnational units will compete economically on the basis of productivity and quality of life provided for its citizens.

This concept can be combined with two others. First, the natural partnership between ITS and the nascent National Information Infrastructure (NII), a communications network of unprecedented scale, scope and functionality, can provide substantial deployment benefits to both.

Second, the strong trend toward freight and traveler intermodalism provides a critical boost to ITS technologies. This is where ITS can help overcome intermodalism's weak point -- the transfer process -- through information and communication technology.

Pulling these ideas together:

> The strategic vision for ITS, then, is as the integrator of transportation, communications and intermodalism on a regional scale.

This is an ambitious vision and one that will require substantial leadership to achieve the technology deployment and the institutional change that will be needed to achieve such an outcome.

ITS has had a dynamic but short history. Challenges have been overcome in these early years. Many remain for the future. When the *Transportation Quarterly* celebrates its 100th anniversary, I believe we will look back on this time as a seminal period in the history of transportation and one in which a truly intermodal transportation/information infrastructure was deployed, advanced by our ITS program.

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5 Sussman, Joseph M., "ITS Deployment and the 'Competitive Region,'" *ITS Quarterly*, ITS America, Washington, DC, Spring 1996. N.B. This article appears in Section II of this volume.

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