INTELLIGENT TRANSPORTATION SYSTEMS

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Contents

Summary

This paper examines the concept of intelligent transportation systems (ITS) as a method for improving the productivity of existing transportation systems and the vehicles that use them. ITS systems are expected to have positive mobility effects as well as contribute to improved air quality and energy conservation. Thus they are a potentially important method for sustaining and improving mobility.

ITS is a set of technologies applied to transportation infrastructure and vehicles to improve their performance. More specifically, ITS consists of the application of established communications, control, electronics, and computer hardware and software technologies to transportation systems. The paper examines in some detail a broad range of ITS technologies and the benefits they are both having and expected to have. These benefits include improved mobility, travel time, throughput, cost savings, improved safety as well as air quality and economic development benefits. While these benefits are occurring the potential for greater benefits is on the horizon. However, there are a number of barriers to deployment beyond just the technical. The paper considers a set of these barriers including problems in regional deployment, intergovernmental relations, public and private sector role expectations, privacy, liability issues and perceived dis-benefits. These topics are summarized and globally assessed in the conclusions.

1. Introduction

Transportation goals and technology have always been intimately linked. The Intelligent Transportation Systems (ITS) technology of today is contributing to improved transportation just as the steam and internal combustion engine technologies of the industrial revolution contributed to enhanced transportation then. The goals of this paper are to explain what ITS is and how it is or is not contributing to improved transportation. In brief, ITS is the application of computer and information technology to transportation systems in the hope of making them more efficient and productive. Before setting off to examine the contribution ITS is or is not making it is important to describe the context within which ITS and transportation systems are operating in at the beginning of the twenty-first century.

1.1. The Context: Transportation, Technology and Economic Development

The industrial revolution generated an enormous demand for mobility while at the same time producing new technology that created steam powered trains and later internal combustion vehicles. When this technology was coupled with the huge road, rail and water infrastructure investments, the early twentieth century witnessed great progress toward achieving the primary goals of that era: transport efficiency and mobility. By the mid-twentieth century transportation safety had gained policy-makers' attention and again technologies were developed and policy measures were adopted to improve safety. The 1960s ushered in a period where environmental and equity goals of society increasingly impacted the transport sector. Again, technology, process innovations and public policy all served to reduce environmental residuals produced by transportation and other sources on the one hand, and to improve access to transportation for income constrained individuals and groups on the other. As the last quarter of the twentieth century unfolded, American competitiveness and economic development became important goals as the information or knowledge era replaced the industrial age. During this period a new generic technology in the form of computer and information technology was created and gradually a new information technology business model emerged that helped address the competitiveness issue. In so doing it also created a new technology for achieving transportation goals.

The reason for briefly recapping different eras of U.S. economic and technological development was to show first of all how intertwined technology, economic growth and the development of transportation systems are. A second and perhaps more important reason was to illustrate that as the U.S. society and economy grew, societal goals and concerns expanded and became more complicated. As this occurred the original transportation goals of mobility and efficiency were increasingly complemented with safety, environmental, energy conservation, equity and fairness, and finally competitiveness and economic development goals. This broadening of objectives expanded the range of actors in transport policy and operations decision-making. As a consequence, the institutional framework for transportation has been forced to accommodate an ever wider and more complex range of interests and stakeholders. In short, there is an ever increasing number of groups that have standing in the transportation policy making and decision process.

The widening range of stakeholders and policy participants is generating more complex decision conflicts that in turn slow consensus formation and thus increase significantly the cost of transportation infrastructure. Internalizing a wider range of stakeholders and goals in transport decision-making (at the national, state/provincial and local levels) tends to slow, complicate, and even stymie the provision of needed infrastructure. This has motivated a search for better process technologies for managing multi-actor complex decision processes and at the same time it has induced a search for non-traditional ways to increase the productivity of existing transportation systems.

The vision of ITS is one of applying computer and information technology to transportation systems and vehicles to raise the capacity of existing infrastructure at a total social cost that is less than the cost of building more physical capacity. This vision, it is believed, may be more acceptable to potentially adversely impacted neighborhood groups, environmentalists and energy conservationists as well as those with constrained incomes. There are however a number of impediments to achieving this including the technology itself and a host of institutional factors. The institutional factors include intergovernmental relations, societal issues such as equity, privacy, role relationships between the public and the private sectors, user acceptance, legal and liability issues and acceptance by traditional transportation systems managers, planners, policy makers and politicians. These factors and related issues are examined as part of this assessment of ITS.

1.2. Defining Intelligent Transportation Systems (ITS)

One way to define ITS is as a set of information technologies applied to transportation infrastructure and vehicles to improve their performance. Expanding on this, then, ITS has been viewed by transportation researchers as the application of established communications, control, electronics, and computer hardware and software technologies surface transportation systems to improve their capacity and performance. While there are many other definitions this captures most of the important points cited by others. It is important to note that improved performance means many things including more qualitative factors such as access, environment, equity and competitiveness. This definition is used in the chapter as the cornerstone definition. Within this definitional framework there are many specific technologies and technological systems, and technical applications. These refinements and nuances are examined below in more detail.

1.3. ITS and the Traditional Transportation Community

ITS is a new approach for the traditional transportation community where there has been difficulty in defining ITS and adapting it in a culture that has focused mostly on developing efficient and effective ways of pouring concrete and laying asphalt to build and maintain durable roads and bridges. The potential promise of ITS has created a new dynamism in the surface transportation community and is contributing to a growing emphasis on improving transport operations and underlying systems. The energy of this dynamism and the benefits it produces are the focus of the following analysis.

1.4. Chapter Organization

The chapter is organized into several major subparts beyond this Introduction. The next part examines the technology and the ways it is used to provide transportation services. This serves as the platform for the next part of the analysis where the benefits of ITS are defined and evaluated. In this assessment both quantitative and qualitative benefits are examined. Once the benefits have been assessed the chapter moves next to an identification and examination of significant issues and barriers to deployment. The final part of the chapter presents the conclusions and leaves the reader with some questions about the future of ITS.

2. The Technology and Related Services

The base technologies in ITS are, for the most part, not new but well-established technologies. ITS includes communication technologies (e.g., global positioning, the Internet, and radio and cellular telephone communication), control (e.g., sensors and sensor dependent feedback systems, transponders and related bar code technologies), electronics (e.g., computers and electronic memory devices) and computer hardware and software. However, it is the integrated application of these technologies to provide a host of transportation services that enables improved productivity and performance of traditional infrastructure.

Transportation services that increasingly depend on ITS technologies are: 1) travel and traffic management; 2) public transportation management; 3) electronic payment; 4) information management; 5) commercial vehicle operations; 6) advanced vehicle safety systems; and 7) emergency management. For each of these there are a number of systems that are supported by ITS technologies (Table 1).

Travel and Traffic Management	**Commercial Vehicle Operations**
Pre-trip travel information	Commercial vehicle electronic clearance
En-route driver information	Automated roadside inspections
Route guidance	On-board safety monitoring
Ride matching and reservations	Comm. vehicle administrative processes
Traffic control	Hazardous material incident response
Incident management	Commercial fleet management
Travel demand management	**Advanced Vehicle Safety Systems**
Emissions testing and mitigation	Longitudinal collision avoidance
Highway-rail intersection	Lateral collision avoidance
Public Transportation Management	Intersection collision avoidance
Public Transportation Management	Vision enhancement for crash avoidance
En-route transit information	Safety readiness
Personalized public transit	Pre-crash restraint deployment
Public travel security	Automated vehicle operation
Electronic Payment	**Emergency Management**
Electronic payment services	Notification and personal security
Information Management	Emergency vehicle management
Archived data functions	

Table 1: Intelligent Transportation Systems Transportation Services

To illustrate how the technologies are used to support the delivery of transportation services (Table 1) several examples are described below. The Internet is used in many U.S. metropolitan areas to provide pre-trip travel information, ride matching and reservation services and personalized public transit assistance. Sensor and video surveillance systems provide information needed for traffic control, en-route driver information, incident management, travel demand management and en-route transit information. Without transponders and related bar code technologies the ability to provide electronic payment services, commercial vehicle electronic clearance, automated roadside safety inspections, and emergency notification and personal security would be seriously constrained. Computer simulation models and algorithms are used to forecast traffic conditions on a faster than real time basis. These models along with their hardware and software will become increasingly critical for providing timely en-route driver and transit information, and for traffic management and control in metropolitan areas and heavily developed corridors. While this description is but a sampling of the ways in which ITS is enhancing the delivery of transportation services and defining new service areas, it is illustrative of how these technologies are being used. The next part of the chapter provides an assessment of how ITS is contributing to improved productivity and the performance of surface transportation systems.

3. Benefits

ITS is viewed as an effort to channel technology applications to improve the performance of surface transportation systems in many ways. To this end it is expected to improve mobility (i.e., reduce congestion), reduce transportation-generated environmental impacts and energy consumption, enable improved safety, enhance quality of life including improved economic viability of communities, and increase the productivity of existing infrastructure. In this part of the paper, the benefits of ITS are assessed. The assessment is organized around a four-category synthesis of the list of user services described above: advanced traveler information systems (ATIS); advanced traffic management systems (ATMS); advanced public transportation systems (APTS); and commercial vehicle operations (CVO).

3.1. Improved Mobility, Travel Time and Throughput

As noted in the introduction, transport officials and policy makers envision that ITS will increase the use and therefore productivity of existing surface transportation infrastructure, thus reducing the need to construct new infrastructure. While this goal is unrealistic in that some new infrastructure will be needed regardless of operational improvements, it is not unrealistic to expect ITS to reduce the need for new infrastructure by raising the capacity of existing infrastructure. Time savings and throughput, and thus improved mobility for personal and commercial travel, are envisioned to occur across several broad ITS application categories including traveler information, traffic management, public transportation systems and commercial vehicle systems as described below.

3.1.1. Advanced Traveler Information Systems

Advanced traveler information systems (ATIS) collect and synthesize traffic information from a number of sources (helicopter/airplane observation, driver call-ins, video surveillance, etc.) and disseminate it to travelers (via radio, telephone, television and the Internet). This information enables travelers to choose more optimal routes, modes and departure times thus reducing travel times and increasing throughput while at the same time reducing total network delay from both recurring and non-recurring incidents.

The evidence on mobility improvement and timesaving impacts of ATIS are spotty but supportive of the expectation that they will have the desired positive effect. An assessment of delay savings due to motorist information in the Information for Motorists (INFORM) program in Long Island, N.Y. found delay savings for motorists as high as 1900 vehicle hours for a peak incident and 300,000 vehicle-hours incident-related delay annually. A test of in-vehicle navigation devices as part of the Orlando based TravTek program found that for non-local drivers wrong turn probability decreased by 33 percent (relative to using maps), travel time decreased by about 20 percent and travel planning time by 80 percent. While these cases suggest that ATIS both improves mobility and reduces travel time, another demonstration test in Chicago, the ADVANCE Project, showed that dynamic route guidance on arterials supported with traffic flow data from vehicle probes generated no time savings. However, several contingencies including limited probe data, small sample size and a large standard deviation marked this ITS demonstration project. The weight of the admittedly limited outcome information is that ATIS improves mobility and reduces travel time.

3.1.2. Advanced Traffic Management Systems

The productivity of existing surface transportation systems could be improved considerably if traffic flow could be smoothed over existing conditions. Traffic management can improve mobility by improving the flow of traffic during non-incident and incident conditions. Improved communications and better sensor-supported traffic information (and related simulation algorithms) enable traffic managers to adjust traffic control devices (e.g., dynamic signal timing, variable message sign information, incident response procedures) which in turn improves flow conditions in both congested and uncongested conditions.

Evaluation of the initial deployment of a Maryland program in the U.S. utilizing automated surveillance with lane sensors and video cameras found the system resulted in a 5 percent decrease in delay due to non-recurrent congestion. A longitudinal assessment of an integrated ramp metering traffic management system in Seattle, Washington found that, while traffic volume increased between 10-100 percent for segments along the I-5 freeway, traffic speeds ranged from unchanged to 20 percent faster. In another case in Los Angeles, California implementation of a computerized signal control system it is estimated that travel time decreased by 18 percent, average speeds increased by 16 percent and delays decreased by 44 percent. The results from deployment of a similar system in Toronto, Canada showed an 8 percent decrease in travel time and a 17 percent decrease in delay. Similar results were obtained in a deployment of a closed-loop computerized signal system in Abilene, Texas. Further, the Institute of Transportation Engineers estimates that advanced freeway management systems used in support of incident management could reduce delays from incidents up to 45 percent. In short, automated traffic surveillance, ramp metering and computerized signalization systems all appear to contribute to travel-time savings and reduced delays.

Electronic tolling is another technology that is increasingly being implemented in support of traffic management. On the Tappan Zee Bridge in New York City electronic toll lanes accommodate up to 1000 vehicles per hour; manned toll lanes handle about 400 vehicles per hour. After the adoption of the multi-jurisdictional E-Zpass electronic toll collection system, traffic speeds now average 25 mph compared to a bottlenecked 8-12 mph before implementation.

In summary, the evidence suggests that ATMS offers considerable time savings across the deployment of multiple technologies including automated surveillance and related communication components, ramp metering, computerized signalization and electronic tolling. Possible benefits from these technologies as they are improved could be quite large.

3.1.3. Advanced Public Transportation Systems

Public transportation like other transportation modes can improve travel time by more efficient vehicle operation and by improving transportation network infrastructure. To date benefits have been observed from the deployment of automatic vehicle location (AVL) systems based on GPS or LORAN (signpost triangulation). For example, a deployment in Baltimore, Maryland yielded a 23 percent improvement in on-time performance and Kansas City, Missouri reported a 12 percent improvement from implementation of a similar system. Further, a deployment of AVL in Milwaukee, Wisconsin resulted in a 28 percent decrease in delays of more than one minute. Finally, a deployment in Recife, Brazil was used to induce transit franchisers to operate on assigned routes and on schedule. AVL is most successful when combined with computer-aided dispatch (CAD).

3.1.4. Commercial Vehicle Operations

The reduction of time involved in transporting cargo (inputs to producers and outputs to markets and consumers) is an important component of competitiveness. Several ITS systems and services can be expected to reduce commercial vehicle travel time. Vehicle monitoring (e.g., with GPS) and on board communication systems tied to central dispatching systems have to date provided the greatest time savings. Schneider Trucking Company of Green Bay, Wisconsin, utilizes such a system and reports that it has eliminated the need for driver check-in telephone calls saving about 2 hours per day of driver time. The saved time is now used driving, thus improving productivity and customer satisfaction. Frederick Transport of Dallas, Texas reports that their system results in drivers being able to drive between 50 and 100 miles more per day with an average mileage increase of 9 percent per day. Best Line (Minneapolis, Minnesota) estimates similar time saving. The NOVA Group, Ltd. is a diversified transportation company and developer of a dispatching software product, Dispatch ToolsTM. Before-after (implementation of the software) measures of deliveries by a panel of drivers and dispatchers showed an increase of 24 percent in productivity as measured by deliveries per driver hour. An unanticipated benefit was a decrease in dispatcher stress and improved communication between the dispatcher and drivers. These examples show one of the ways ITS is contributing to a reduction in business transaction costs.

Commercial vehicles must stop at inspection stations and for processing at ports of entry. This time is significant as vehicles cross state- and national boundaries. Pre-clearance coupled with electronic communications and automated monitoring (smart cards and transponders) could all but eliminate much of the regulatory delay involved in inspections. Various systems are in use in many states thus indicating that time savings are being achieved.

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Biographical Sketches

Dr. Stough began his education with an undergraduate degree in international trade and economics from the Ohio State University. This was followed with a master's degree in economic geography from the University of South Carolina and then a Ph.D. in geography and environmental engineering at the Johns Hopkins University. In the 1970s he built a program in environmental psychology while directing an urban design and metropolitan quality of life program in the Center for Metropolitan Planning and Research while at the Johns Hopkins University. In 1977 he moved to the College of Charleston in South Carolina where he founded a masters degree program in public administration and the Center for Metropolitan Development and policy. While in Charleston he conducted numerous sponsored research projects on regional development and coastal management.

In 1983 he moved to the School of Public and Environmental Affairs at Indiana University where he served as chair of the urban and regional faculty statewide and in 1989 as acting Associate Dean. Much of his research while at Indiana University focused on regional economic development issues and policy aimed at addressing structural change in the urban economies of Indiana and the Mid West. He became increasingly active in international training and consulting during his stay at Indiana with assignments in the Caribbean and Europe and as a visiting faculty member at Erasmus University in the Netherlands.

In 1990 he moved to the George Mason University to help establish a new Institute in Public Policy which in 2000 became the School of Public Policy. He holds the NOVA endowed chair in public policy and is professor of public policy. His positions while at George Mason University include associate director of the Institute, founding director of the Ph.D. program in public policy, director of the International Commerce and Policy masters degree program, associate dean for academic affairs and now associate dean for research and external relations. He also founded the Center for Regional Analysis and the Center for Transportation, Operations and Logistics. Currently, he directs the Mason Enterprise Center, a university-wide center that directs the university's entrepreneurship programs. He also directs the $25 million National Center for ITS Deployment Research, a multi-university center that conducts research on technical and institutional barriers to the implementation of intelligent transportation systems technologies.

Dr. Stough has been the principal investigator for more than $40 million of sponsored research while at George Mason University. Much of this has been in the field of transportation and focused on institutional and policy barriers to the adoption of new technology across all transportation modes including space. At the same time he continued to publish extensively in the field of regional economic analysis and policy. His international work expanded considerably during this period with a visiting professorship at Leiden University, research and consulting work in Spain, Sweden, the Netherlands and the European Union in

Europe, and in Australia, China, Taiwan, Japan, Korea, Hong Kong and India in Asia. During this period a number of research and faculty exchange programs were developed with universities in these counties.

Dr. Stough is editor of the international journal, *The Annals of Regional Science*, is co-editor of *The Journal of Public Affairs Research*, a joint English and Chinese journal, and serves on the editorial board of several other international journals. He is currently the President of the Western Regional Science Association and has served on the board of the North American and European Regional Science Associations. He has published extensively with twelve books on topics ranging from surface and air transportation to regional economic policy and analysis and more than two hundred scholarly and professional papers and reports. His research has focused on regional economic analysis, transportation, regional and transport modeling, logistics, public policy analysis and technology-led economic development. Dr. Stough teaches courses in public policy, macro policy, urban and regional policy, regional economic analysis, planning and policy, and environmental planning and policy.

Guang Yang began his education with an undergraduate degree in economics from Hebei University, Baoding, China in 1991. Between 1991 and 1994, he received scholarship awards for three consecutive years and graduated in 1995. Between 1995 and 1998, he worked on his master's degree in demography at the Population Research Institute of Beijing University, specializing in demography and economics. He graduated in 1998 with various academic honors including Guanghua Scholarship, Exemplar Youth Scholarship, and Standing member of Beijing University Graduate Students' Association (1996-1997). Currently, he is working on his Ph.D. in public policy at the School of Public Policy (SPP), George Mason University.