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EXPLAINING INTERNATIONAL IT APPLICATION LEADERSHIP:

Intelligent Transportation Systems

Stephen Ezell | January 2010

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Executive Summary: Intelligent Transportation Systems

Information technology (IT) has transformed many industries, from education to health care to government, and is now in the early stages of transforming transportation systems.

Information technology (IT) has transformed many industries, from education to health care to government, and is now in the early stages of transforming transportation systems. While many think improving a country's transportation system solely means building new roads or repairing aging infrastructures, the future of transportation lies not only in concrete and steel, but also increasingly in using IT. IT enables elements within the transportation system—vehicles, roads, traffic lights, message signs, etc.—to become intelligent by embedding them with microchips and sensors and empowering them to communicate with each other through wireless technologies. In the leading nations in the world, ITS bring significant improvement in transportation system performance, including reduced congestion and increased safety and traveler convenience. Unfortunately, the United States lags the global leaders, particularly Japan, Singapore, and South Korea in ITS deployment. For the most part, this has been the result of two key factors: a continued lack of adequate funding for ITS and the lack of the right organizational system to drive ITS in the United States, particularly the lack of a federally led approach, as opposed to the “every state on its own approach” that has prevailed to date.

This report examines the promise of ITS, identifies the global leaders in ITS and why they are leaders, discusses the reasons for the U.S. failure to lead, and proposes a number of recommendations for how Congress and the Administration can spur robust ITS deployment. If the United States is to achieve even a minimal ITS system, the federal govern-

ment will need to assume a far greater leadership role in not just ITS R&D, but also ITS deployment. In short, it is time for the U.S. Department of Transportation to view ITS as the 21st century, digital equivalent of the Interstate highway system, where, like then, the federal government took the lead in setting a vision, developing standards, laying out



routes, and funding its construction. Just as building the Interstate Highway System did not mean an abandonment of the role of states, neither does this new role; but just as building the Interstate required strong and sustained federal leadership, so too does transforming our nation's surface transportation through ITS. Accordingly, this report recommends that in the reauthorization of the surface transportation act, Congress should:

- **Significantly increase funding for ITS at the federal level, by \$2.5 to \$3 billion annually, including funding for large-scale demonstration projects, deployment, and the ongoing operations and maintenance of already-deployed ITS. Specifically, the next surface transportation authorization bill should include \$1.5 to \$2 billion annually in funding for the deployment of large-scale ITS demonstration projects and should also provide dedicated, performance-based funding of \$1 billion for states to implement existing ITS and to provide for ongoing operations, maintenance, and training for already deployed ITS at the state and regional levels.**
- **Expand the remit of the ITS Joint Program Office to move beyond R&D to include deployment.**
- **Tie federal surface transportation funding to states' actual improvements in transportation system performance.**
- **Charge DOT with developing, by 2014, a national real-time traffic information system, particularly in the top 100 metropolitan areas, with this vision including the significant use of probe vehicles.**
- **Authorize a comprehensive R&D agenda that includes investments in basic research, technology development, and pilot programs to begin moving to a mileage-based user fee system by 2020.**

Transportation systems are networks, and much of the value of a network is contained in its information: For example, whether a traffic signal "knows" there is traffic waiting to pass through an intersection; whether a vehicle is drifting out of its lane; whether two ve-

hicles are likely to collide at an intersection; whether a roadway is congested with traffic; what the true cost of operating a roadway is; etc. Intelligent transportation systems empower actors in the transportation system—from commuters, to highway and transit network operators, to the actual devices, such as traffic lights, themselves—with actionable information (that is, intelligence) to make better-informed decisions, whether it's choosing which route to take; when to travel; whether to mode-shift (take mass transit instead of driving); how to optimize traffic signals; where to build new roadways; or how to hold providers of transportation services accountable for results. This information can be used both to maximize the operational performance of the transportation network and to move towards performance based funding for transportation systems. ITS also represent an emerging new infrastructure platform, from which a whole host of new products and services are likely to emerge, many which can barely be imagined today.

Intelligent transportation systems include a wide and growing suite of technologies and applications. ITS applications can be grouped within five summary categories: 1) Advanced Traveler Information Systems provide drivers with real-time information, such as transit routes and schedules; navigation directions; and information about delays due to congestion, accidents, weather conditions, or road repair work. 2) Advanced Transportation Management Systems include traffic control devices, such as traffic signals, ramp meters, variable message signs, and traffic operations centers. 3) ITS-Enabled Transportation Pricing Systems include systems such as electronic toll collection (ETC), congestion pricing, fee-based express (HOT) lanes, and vehicle miles traveled (VMT) usage-based fee systems. 4) Advanced Public Transportation Systems, for example, allow trains and buses to report their position so passengers can be informed of their real-time status (arrival and departure information). 5) Fully integrated intelligent transportation systems, such as vehicle-to-infrastructure (VII) and vehicle-to-vehicle (V2V) integration, enable communication among assets in the transportation system, for example, from vehicles to roadside sensors, traffic lights, and other vehicles.

ITS deliver five key classes of benefits by: 1) increasing safety, 2) improving operational performance, particularly by reducing congestion, 3) enhancing mobility

and convenience, 4) delivering environmental benefits, and 5) boosting productivity and expanding economic and employment growth.

ITS are contributing to a fundamental reassessment of vehicle safety. Whereas most developments in transportation safety over the past 50 years were designed to protect passengers in the event of a crash, VII and V2V systems such as Japan's Smartway or the United States' IntelliDrive are being designed to help motorists avoid the accident altogether. For example, the U.S. IntelliDrive system could potentially address 82 percent of vehicle crash scenarios involving unimpaired drivers.

ITS maximize the capacity of infrastructure, reducing the need to build additional highway capacity. For example, applying real-time traffic data to U.S. traffic signal lights can improve traffic flow significantly, reducing stops by as much as 40 percent, reducing travel time by 25 percent, cutting gas consumption by 10 percent (1.1 million gallons of gas annually), and cutting emissions by 22 percent (cutting daily carbon dioxide emissions by 9,600 tons). ITS can contribute significantly to reducing congestion, which costs U.S. commuters 4.2 billion hours and 2.8 billion gallons of fuel each year, costing the U.S. economy up to \$200 billion per year. Overall, ITS can reduce congestion by as much as 20 percent or more. ITS also enable transportation agencies to collect the real-time data needed to measure and improve the performance of the transportation system, making ITS the centerpiece of efforts to reform surface transportation systems and hold providers accountable for results.

By improving the operational performance of the transportation network, ITS enhance driver mobility and convenience, deliver environmental benefits, and even boost productivity and economic growth. For Japan, ITS have been crucial as the country strives to meet its goal to reduce, by 2010, CO₂ emissions by 31 million tons below 2001 levels, with 11 million tons of savings come from improved traffic flow and another 11 million tons of savings from more effective use of vehicles. For many countries, ITS represents a rapidly expanding, export-led growth sector which contributes directly to national economic competitiveness and employment growth. For example, the U.S. Department of Transportation has estimated that the field of ITS

could create almost 600,000 new jobs over the next 20 years, and a study of ITS in the United Kingdom found that a £5 billion investment in ITS would create or retain 188,500 jobs for one year.

Intelligent transportation systems deliver superior benefit-cost returns when compared to traditional investments in highway capacity. Overall, the benefit-cost ratio of systems-operations measures (enabled by intelligent transportation systems) has been estimated at about 9 to 1, far above the addition of conventional highway capacity, which has a benefit-cost ratio of 2.7 to 1. A 2005 study of a model ITS deployment in Tucson, Arizona, consisting of 35 technologies that would cost \$72 million to implement, estimated that the average annual benefits to mobility, the environment, safety, and other areas would total \$455 million annually, a 6.3 to 1 benefit-cost ratio. If the United States were to implement a national real-time traffic information program, the GAO estimates the present value cost of establishing and operating the program would be \$1.2 billion, but would deliver present value benefits of \$30.2 billion, a 25 to 1 benefit-cost ratio.

Despite their technical feasibility and significant benefit-cost ratios, many nations under-invest in ITS, partly because there are a significant number of challenges involved in developing and deploying ITS. While some ITS, such as ramp meters or adaptive traffic signals, can be deployed locally and prove effective, the vast majority of ITS applications—and certainly the ones positioned to deliver the most extensive benefits to the transportation network—must operate at scale, often at a national level, and must involve adoption by the overall system and by individual users at the same time to be effective, raising a unique set of system interdependency, network effect, and system coordination challenges. For example, VII systems like IntelliDrive must work on a national basis to be truly effective: it does a driver little good to purchase an IntelliDrive equipped vehicle in one state if it doesn't work in other states the driver frequents. Likewise, drivers are not likely to demand on-board units capable of displaying real-time traffic information if that information is unavailable. Many ITS systems work optimally at scale: For example, it makes little sense for states to independently develop a vehicle miles traveled usage-fee system because, in addition to requiring an on-board device in vehicles (ideally as part of the original factory-installed

equipment), VMT requires a satellite system and a back-end payment system, and it makes little sense for states to independently replicate these infrastructure investments. Moreover, auto manufacturers would not want to have to make or install up to 50 different on-board devices to accommodate states' potentially differing implementations of a VMT system.

But whether it's with regard to ITS systems that face systemic barriers or those that can be deployed locally, many regions, states, and countries underinvest in ITS. This happens, in part, because transportation funding is often allocated without consideration of performance, giving transportation planners little incentive to preference investments that can have a maximum impact on optimizing system performance. Part of the problem is that state and local transportation agencies were created to build and maintain infrastructure, not to manage transportation networks, and thus see themselves as "builders of pieces" and not "managers of a system" and therefore place more emphasis on building new roads than ensuring the system functions optimally. For companies developing new ITS products and services, the effort entails much higher risk than does development of many other products and services, in part because governments are key buyers, and in some countries, such as the United States, they have demonstrated at best mixed signals as reliable purchasers. Apart from being generally underfunded, another challenge for ITS projects is that they often have to compete for funding with conventional transportation projects—fixing potholes, repairing roads, building new ones, etc.—that may be more immediately pressing but don't deliver as great long-term returns. Finally, ITS face a range of institutional and organizational barriers, including limited understanding of the technology and jurisdictional challenges, such as which level of government—federal, state, county, city, public authority, or interstate compact—has responsibility for or jurisdiction over ITS deployments.

But while intelligent transportation systems face a number of challenges, none of them are insurmountable, and many nations have overcome them. Japan, South Korea, and Singapore appear to have done so the best. Japan leads the world in ITS based on the number of citizens benefitting from an impressive array of operationally deployed intelligent transportation systems. Japan's VICS, Vehicle Information and Communica-

tion Systems, provides an up-to-the minute, in-vehicle digital data communication system providing traffic information to drivers through an on-board telematics unit. VICS, which makes extensive use of probe data to generate real-time traffic information, launched in 1996 and has been available nationwide since 2003. Following upon VICS, Japan is now launching Smartway as "Version 2.0" of the country's state-of-the art ITS service. The system will be able to marry knowledge of the vehicle's location on the roadway with context-specific traffic flow information, enabling it, for example, to warn the driver, via voice instruction, "You are coming up to a curve with congestion backed up behind it, slow down immediately." Impressively, Smartway evolved from concept development in 2004, to limited deployment in 2007, to initial national deployment in 2010, an extremely fast development timeline. At least 34 million vehicles have access to real-time, in-vehicle traffic information in Japan, and citizens can view maps with real-time traffic information for most roads in Japan over the Internet. Lastly, Japan operates a single national standard for electronic tolling, with 68 percent of vehicles using ETC. The country invests just under \$700 million a year in ITS.

South Korea will invest \$3.2 billion in ITS deployment from 2008 to 2020, about \$230 million annually, as part of the country's ITS Master Plan. South Korea built its ITS infrastructure on a city-by-city basis, establishing four initial "ITS Model Cities" that implemented: 1) adaptive traffic signal control, 2) real-time traffic information, 3) public transportation management, and 4) speed violation enforcement in these model cities. 29 South Koreans have now deployed similar ITS implementations. 9,300 buses and 300 bus stops have deployed real-time bus location and status notification systems. South Koreans use T-money, an electronic money smart card (or mobile phone application) to make 30 million contactless transactions per day on public transit. The country's Hi-Pass ETC system covers 50 percent of highway roads (expanding to 70 percent coverage by 2013) and is used by 31 percent of vehicles.

Singapore was the first country in the world to introduce an electronic congestion pricing system in 1998 (and has actually had some form of congestion charging in place in its city center since 1975). The country generates and disseminates real-time traffic informa-

tion through a fleet of 5,000 probe vehicles. Singapore has deployed adaptive computerized traffic signals nationwide, installed real-time bus status screens at most bus stops, and launched a national parking guidance system in April 2008. Singapore's i-Transport system is at the cutting edge of predictive traffic flow modeling based on the use of historic and real-time traffic data.

In contrast to the leaders, the United States lags in ITS deployment, particularly with regard to provision of real-time traffic information, progress to date on vehicle-to-infrastructure and vehicle-to-vehicle integration, adoption of computerized traffic signals, and maximizing the effectiveness of its already fielded ITS systems. While the United States certainly has pockets of strengths with regard to ITS in particular regions and applications—including use of variable rate highway tolling, electronic toll collection, certain advanced traffic management systems such as ramp metering, and an active private sector market in telematics and travel information provision—overall the implementation of ITS varies significantly by state and region, thus tending to be sporadic and isolated and not connected into a nationally integrated “intelligent transportation system.” As one illustration of U.S. challenges in ITS, the percentage of U.S. metropolitan areas delivering real-time highway travel time and highway travel speed information to the public in 2007 was, respectively, 36 percent and 32 percent, while for arterial roadways, only 16 percent of U.S. metropolitan areas disseminate real-time travel speed information and only 19 percent distribute real-time travel time data.

For the most part, U.S. challenges in ITS have been the result of two key factors: a continued lack of adequate funding for ITS; and the lack of a federally led approach, as opposed to the “every state on its own approach” that has prevailed to date. At the federal level, the U.S. ITS effort focuses on research, is funded at \$110 million annually, and operates out of the U.S. Department of Transportation’s Research and Innovative Technology Administration’s (RITA) ITS Joint Program Office (JPO). To reorganize and reanimate the U.S. ITS effort, on January 8, 2010, RITA unveiled a new, five-year “ITS Strategic Research Plan, 2010–2014.” While the Strategic Plan represents an important step forward, the United States needs to make a

fundamental transition from a focus mostly oriented around research to include a much greater focus on deployment and endeavor to accelerate the speed at which ITS technologies reach the traveling public.

In explaining international leadership in intelligent transportation systems, policy factors appear to be much more important than non-transportation policy factors. Overall, countries leading the world in ITS deployment: 1) demonstrate national level commitment and vision, 2) make substantial investments in ITS deployment, and 3) feature strong government leadership in crafting a clearly articulated ITS vision, setting a national agenda, convening relevant stakeholders, and spearheading implementation. Many of these countries enjoy a high degree of centralization in ITS decision making and deployment, and in some cases federal governments (as in Japan) have direct control over roadways. But these countries also invest in ITS. For example, South Korea and Japan each invest more than twice as much in intelligent transportation systems as a share of GDP than the United States. Further, these countries recognize ITS as a “force-multiplier” for their transportation networks that will enable a shift to a performance-based transportation funding system, have built their ITS infrastructure through public-private partnerships, and view their ITS investments as a platform that will lead to the creation of new value-added products and services, many of which can scarcely be foreseen today.

Over the next five years, the United States is poised to invest more than \$500 billion on the nation’s surface transportation infrastructure. Intelligent transportation systems must be a critical component of these investments in order to maximize the operational performance of the transportation system and attain the significant benefits enumerated in this report. If the United States does not take advantage of the current opportunity to significantly fund ITS as part of the next surface transportation authorization, it risks not only falling further behind world leaders and other developed economies in ITS, but also losing ground to rising countries such as China and India, which are beginning to make substantial investments in ITS development and deployment.

Explaining International IT Leadership: Intelligent Transportation Systems

Information technology has already revolutionized many industries, and now appears poised to transform countries' transportation systems by bringing information to bear on the transportation network.

Imagine knowing real-time traffic conditions for virtually every highway or arterial roadway in the country and having that information available on multiple platforms, both in-vehicle and out. Imagine driving down an expressway with a telematics unit that, combining GPS with real-time traffic information, could audibly alert you that you are approaching a blind curve with traffic backed up immediately ahead and that you need to brake immediately. Envision enjoying a mobile device that can display real-time traffic information (while simultaneously helping to generate that information), optimize your route accordingly, and electronically pay tolls when you're on the highway (or fares when you're using mass transit). Imagine a performance-based transportation system that makes capital investment decisions regarding competing transportation projects based on a detailed understanding of their cost-benefit trade-offs enabled by meticulously collected data.

Information technology (IT) has already revolutionized many industries, and now appears poised to transform countries' transportation systems. Indeed, IT is likely to emerge as the major tool to solve surface transportation challenges over the next several decades, as an "infostructure" gets built alongside countries' physical transportation infrastructure. In fact, the scenarios described above are not visionary or futuristic; they are real, already exist in several countries today, and are

available to all countries that focus on developing and deploying them. The scenarios describe applications of intelligent transportation systems (ITS), systems that deploy communications, control, electronics, and computer technologies to improve the performance of highway, transit (rail and bus), and even air and maritime transportation systems. Intelligent transportation systems include a wide and growing suite of technologies and applications such as real-time traffic information



systems, in-car navigation (telematics) systems, vehicle-to-infrastructure integration (VII), vehicle-to-vehicle integration (V2V), adaptive traffic signal control, ramp metering, electronic toll collection, congestion pricing, fee-based express (HOT) lanes, vehicle usage-based mileage fees, and vehicle collision avoidance technologies.

WHY IS ITS IMPORTANT?

Many think improving a country's transportation system solely means building new roads or repairing aging infrastructure. But the future of transportation lies not only in concrete and steel, but also in the implementation of technology, specifically a network of sensors, microchips, and communication devices that collect and disseminate information about the functioning of the transportation system. Transportation systems are really about networks, and much of the value of a network is contained in its information: For example, whether a traffic signal "knows" there is traffic waiting to pass through an intersection; whether a vehicle is drifting out of its lane; whether two vehicles are likely to collide at an intersection; whether a roadway is congested with traffic; what the true cost of operating a roadway is, etc. What intelligent transportation systems do is empower actors in the

transportation system—from commuters, to highway and transit network operators, even down to the actual traffic lights themselves—with actionable information (or, intelligence) to make better-informed decisions, whether it's choosing which route to take; when to travel; whether to mode-shift (take mass transit instead of driving); how to optimize traffic signals; where to build new roadways; what the true cost of roadways are and how best to price their use; or how to hold providers of transportation services accountable for results. The big opportunity at hand is to bring information to bear on transportation networks, transforming them into truly intelligent transportation systems.

UNDERSTANDING INTELLIGENT TRANSPORTATION SYSTEMS

Given the wide range of intelligent transportation systems, it is useful to organize discussion of ITS applications through a taxonomy that arranges them by their primary functional intent (with the acknowledgment that many ITS applications can serve multiple functions or purposes). While this list is not inclusive of all possible ITS applications, it includes the most prominent ones, which are the focus of this report (see Table 1). ITS applications can be grouped within five primary categories: Advanced Traveler Information Sys-

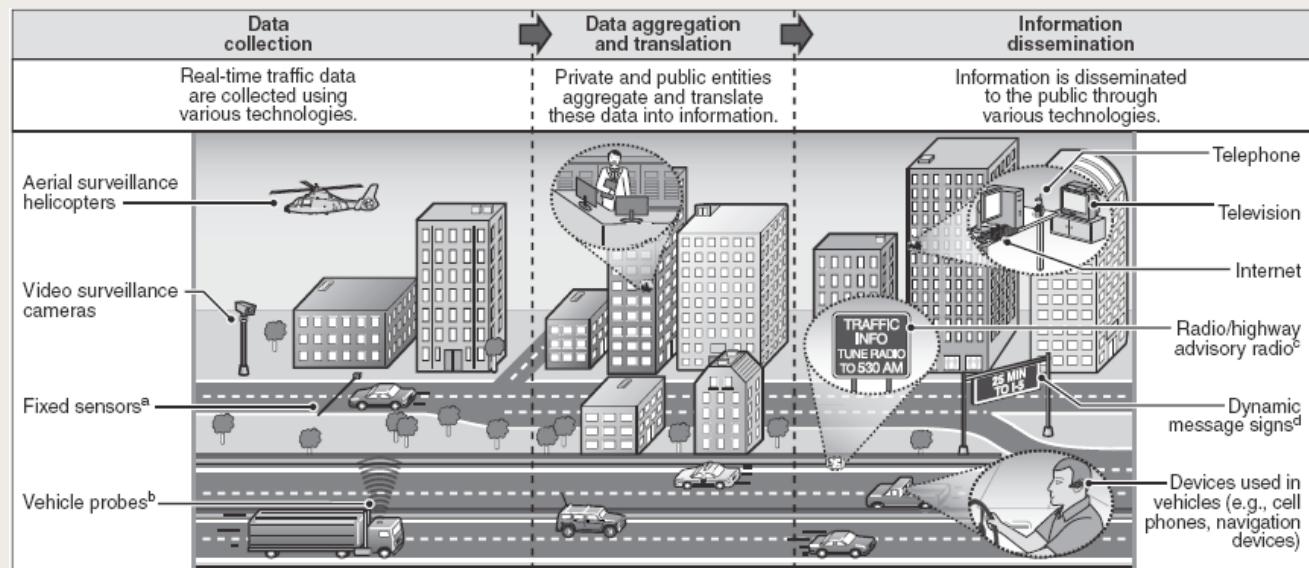
Table 1: Classifying Contactless Mobile Payments Applications¹

ITS Category	Specific ITS Applications
1. Advanced Traveler Information Systems (ATIS)	Real-time Traffic Information Provision Route Guidance/Navigation Systems Parking Information Roadside Weather Information Systems
2. Advanced Transportation Management Systems (ATMS)	Traffic Operations Centers (TOCs) Adaptive Traffic Signal Control Dynamic Message Signs (or "Variable" Message Signs) Ramp Metering
3. ITS-Enabled Transportation Pricing Systems	Electronic Toll Collection (ETC) Congestion Pricing/Electronic Road Pricing (ERP) Fee-Based Express (HOT) Lanes Vehicle-Miles Traveled (VMT) Usage Fees Variable Parking Fees
4. Advanced Public Transportation Systems (APTS)	Real-time Status Information for Public Transit System (e.g. Bus, Subway, Rail) Automatic Vehicle Location (AVL) Electronic Fare Payment (for example, Smart Cards)
5. Vehicle-to-Infrastructure Integration (VII) and Vehicle-to-Vehicle Integration (V2V)	Cooperative Intersection Collision Avoidance System (CICAS) Intelligent Speed Adaptation (ISA)

BOX 1: KEY UNDERLYING TECHNOLOGIES FOR ITS

- **Global Positioning System (GPS).** Embedded GPS receivers in vehicles' on-board units (OBUs, a common term for telematics devices) receive signals from several different satellites to calculate the device's (and thus the vehicle's) position. This requires line of sight to satellites, which can inhibit use of GPS in downtown settings due to "urban canyon" effects. Location can usually be determined to within ten meters. GPS is the core technology behind many in-vehicle navigation and route guidance systems. Several countries, notably Holland and Germany, are using or will use OBUs equipped with satellite-based GPS devices to record miles traveled by automobiles and/or trucks in order to implement user fees based on vehicle miles traveled to finance their transportation systems.
- **Dedicated-Short Range Communications (DSRC).** DSRC is a short- to medium-range wireless communication channel, operating in the 5.8 or 5.9GHz wireless spectrum, specifically designed for automotive uses. Critically, DSRC enables two-way wireless communications between the vehicle (through embedded tags or sensors) and roadside equipment (RSE). DSRC is a key enabling technology for many intelligent transportation systems, including vehicle-to-infrastructure integration, vehicle-to-vehicle communication, adaptive traffic signal timing, electronic toll collection, congestion charging, electronic road pricing, information provision, etc. DSRC is a subset of radio frequency identification (RFID) technology. The technology for ITS applications works on the 5.9GHz band (United States) or the 5.8GHz band (in Japan and Europe). At present, DSRC systems in Europe, Japan, and the United States are generally not compatible (although there are indications that Europe may be trying to migrate to 5.9GHz). In 2004, the U.S. Federal Communications Commission (FCC), atypically for a U.S. regulator, prescribed a common standard for the DSRC band both to promote interoperability and to discourage the limitation of competition through proprietary technologies.²
- **Wireless Networks.** Similar to technology commonly used for wireless Internet access, wireless networks allow rapid communications between vehicles and the roadside, but have a range of only a few hundred meters.³ However, this range can be extended by each successive vehicle or roadside node passing information onto the next vehicle or node. South Korea is increasingly using WiBro, based on WiMAX technology, as the wireless communications infrastructure to transmit traffic and public transit information throughout its transportation network.
- **Mobile Telephony.** ITS applications can transmit information over standard third or fourth generation (3G or 4G) mobile telephone networks. Advantages of mobile networks include wide availability in towns and along major roads. However, additional network capacity may be required if vehicles are fitted with this technology, and network operators might need to cover these costs. Mobile telephony may not be suitable for some safety-critical ITS applications since it may be too slow.⁴
- **Radiowave or Infrared Beacons.** Japan's Vehicle Information Communications System (VICS) uses radio wave beacons on expressways and infrared beacons on trunk and arterial roadways to communicate real-time traffic information. (Arterial roadways are moderate capacity roadways just below highways in level of service; a key distinction is that arterial roadways tend to use traffic signals. Arterial roadways carry large volumes of traffic between areas in urban centers.) VICS uses 5.8GHz DSRC wireless technology.
- **Roadside Camera Recognition.** Camera- or tag-based schemes can be used for zone-based congestion charging systems (as in London), or for charging on specific roads. Such systems use cameras placed on roadways where drivers enter and exit congestion zones. The cameras use Automatic License Plate Recognition (ALPR), based on Optical Character Recognition (OCR) technology, to identify vehicle license plates; this information is passed digitally to back-office servers, which assess and post charges to drivers for their use of roadways within the congestion zone.
- **Probe Vehicles or Devices.** Several countries deploy so-called "probe vehicles" (often taxis or government-owned vehicles equipped with DSRC or other wireless technology) that report their speed and location to a central traffic operations management center, where probe data is aggregated to generate an area-wide picture of traffic flow and to identify congested locations. Extensive research has also been performed into using mobile phones that drivers often carry as a mechanism to generate real-time traffic information, using the GPS-derived location of the phone as it moves along with the vehicle. As a related example, in Beijing, more than 10,000 taxis and commercial vehicles have been outfitted with GPS chips that send travel speed information to a satellite, which then sends the information down to the Beijing Transportation Information Center, which then translates the data into average travel speeds on every road in the city.⁵

Figure 1: Example of Technologies Associated with Real-Time Traffic Information Systems⁶



tems (ATIS), Advanced Transportation Management Systems (ATMS), ITS-Enabled Transportation Pricing Systems, Advanced Public Transportation Systems (APTS), and Fully Integrated ITS Systems (VII and V2V Systems).

ITS APPLICATIONS: DEFINITIONS AND TECHNOLOGIES

Advanced Traveler Information Systems

Perhaps the most-recognized ITS applications, Advanced Traveler Information Systems (ATIS) provide drivers with real-time travel and traffic information, such as transit routes and schedules; navigation directions; and information about delays due to congestion, accidents, weather conditions, or road repair work. The most effective traveler information systems are able to inform drivers in real-time of their precise location, inform them of current traffic or road conditions on their and surrounding roadways, and empower them with optimal route selection and navigation instructions, ideally making this information available on multiple platforms, both in-vehicle and out. As Figure 1 illustrates, there are three key facets to the provision of real-time traffic information: collection, processing, and dissemination, with each step entailing a distinct set of technology devices, platforms, and actors, both public and private. This report will examine several countries' strategies regarding the provision of real-time traffic information.

This category also includes in-car navigation systems and telematics-based services, such as GM's OnStar,

which offer a range of safety, route navigation, crash notification, and concierge services, including location-based services, mobile calling, or in-vehicle entertainment options such as Internet access and music or movie downloads. Vehicles in the United States increasingly have telematics devices, whether a factory-installed GPS system or one purchased after-market, such as those available from Garmin or TomTom. As of 2009, 28 percent of U.S. vehicles carried some form of telematics device, and analysts expect that number to grow to 40 percent of U.S. vehicles by 2012.⁷ By 2012, telematics projects to be a \$2.4 billion market in the United States and a \$9.3 billion market worldwide.⁸

Other advanced traveler information systems make parking easier, as cities from Singapore to Stockholm to San Francisco are deploying systems that indicate to drivers where vacant spaces can be found in the city, and even allow drivers to reserve spaces in advance. Studies have shown that 30 percent or more of urban traffic in large cities consists of drivers circulating as they search for parking.⁹

Advanced Transportation Management Systems

Advanced Transportation Management Systems (ATMS) include ITS applications that focus on traffic control devices, such as traffic signals, ramp metering, and the dynamic (or "variable") message signs on highways that provide drivers real-time messaging about traffic or highway status. Traffic Operations Centers (TOCs), centralized traffic management centers run by cities and states worldwide, rely on information

technologies to connect sensors and roadside equipment, vehicle probes, cameras, message signs, and other devices together to create an integrated view of traffic flow and to detect accidents, dangerous weather events, or other roadway hazards.

Adaptive traffic signal control refers to dynamically managed, intelligent traffic signal timing. Many countries' traffic lights, including the vast majority of the close to 300,000 signalized intersections in the United States, use static, outdated timing plans based on data collected years or decades before.¹⁰ In fact, an estimated 5 to 10 percent of the congestion on major American roadways—amounting to 295 million vehicle hours—is attributed to bad signal timing.¹¹ Giving traffic signals the ability to detect the presence of waiting vehicles, or giving vehicles the ability to communicate that information to a traffic signal, perhaps through DSRC-enabled communication (assuming both the vehicle and traffic signal are DSRC-equipped), could enable improved timing of traffic signals, thereby enhancing traffic flow and reducing congestion.

Another advanced transportation management system that can yield significant traffic management benefits is ramp metering. Ramp meters are traffic signals on freeway entrance ramps that break up clusters of vehicles entering the freeway, which reduces the disruptions to freeway flow that vehicle clusters cause and makes merging safer. About 20 U.S. metropolitan areas use ramp metering in some form.

ITS-Enabled Transportation Pricing Systems

ITS have a central role to play in funding countries' transportation systems. The most common application is electronic toll collection (ETC), also commonly known internationally as "road user charging," through which drivers can pay tolls automatically via a DSRC-enabled on-board device or tag placed on the windshield (such as E-Z Pass in the United States). The most sophisticated countries, including Australia and Japan, have implemented a single national ETC standard, obviating the need, as in the United States, to carry multiple toll collection tags on cross-country trips because various highway operators' ETC systems lack interoperability. This particularly has been a problem for the European Union, although the European Committee for Standardization is working to resolve this challenge (and has made considerable progress).

An increasing number of cities throughout the world have implemented congestion pricing schemes, charging for entry into urban centers, usually at certain peak hours, as a means to not only reduce congestion but also to generate needed resources to fund investments in public transportation and to reduce the environmental impact of vehicles.¹² Singapore, Stockholm, London, Oslo, and Jakarta are just some of the cities that have put congestion pricing systems in place to reduce traffic congestion, smog, and greenhouse gases. By charging more at congested times, traffic flows can be evened out or reduced. As half the world's population now lives in urban areas, some economists believe that urban congestion and emissions will be virtually impossible to reduce without some form of congestion pricing.¹³ For example, in Europe, urban areas account for 40 percent of passenger transport but 53 percent of all transport-related emissions.¹⁴

ITS have a central role to play in financing countries' transportation systems.

Stockholm's congestion pricing scheme yielded immediate results, reducing traffic by 20 percent in the first month alone as many commuters opted for public transportation.¹⁵ Statistics gathered since the full implementation of Stockholm's congestion pricing scheme in 2007 show that the initiative has reduced both traffic congestion and carbon emissions by 15 percent on a sustained basis. Stockholm's congestion pricing scheme has also generated \$120 million in net revenue. If congestion pricing were used in just three to five major American cities, it could save as much fuel as is saved with the fuel economy standards for light vehicles in the United States.¹⁶

High-Occupancy Toll (HOT) lanes—lanes reserved for buses and other high occupancy vehicles but that can be made available to single occupant vehicles upon payment of a toll—are another ITS-enabled mechanism to combat traffic congestion. The number of vehicles using the reserved lanes can be controlled through variable pricing (via electronic toll collection) to maintain free-flowing traffic at all times, even during rush hours, which increases overall traffic flow on a given segment of road. For example, Orange County, California, found that, while HOT lanes represent only

one-third of its highway lane miles, they carry over half of the traffic during rush hours.¹⁷ By the end of 2009, approximately 25 U.S. cities either had deployed or were beginning to plan or implement HOT lane proposals.¹⁸

Another ITS-enabled alternative countries are evaluating for financing their transportation systems is a vehicle miles traveled (VMT) fee system that charges motorists for each mile driven. VMT fee systems represent an alternative to the current fuel taxes and other fees that many countries and states use to finance their transportation systems. Holland's "Kilometerprijs" (price per kilometer) program is slated to be the world's first nationwide VMT system implemented for both passenger vehicles and heavy vehicles. The Kilometerprijs program will replace fixed vehicle (ownership) taxes to charge Dutch citizens by their annual distances driven, differentiated by time, place, and environmental characteristics. The policy, which will begin with distance-based charging for freight transport in 2012, followed by passenger vehicles by 2016, will use advanced satellite technology coupled with an on-board vehicle telematics system to charge travelers based on mileage driven.¹⁹ Germany is already charging for freight transport on this basis. In the United States, the National Surface Transportation Infrastructure Financing Commission recommended in February 2009 moving to a VMT-type "user charge" fee system within a decade,²⁰ and several states, including Oregon, Washington, and Hawaii, are considering doing so as well.²¹

Advanced Public Transportation Systems

Advanced Public Transportation Systems (APTS) include applications such as automatic vehicle location (AVL), which enable transit vehicles, whether bus or rail, to report their current location, making it possible for traffic operations managers to construct a real-time view of the status of all assets in the public transportation system. APTS help to make public transport a more attractive option for commuters by giving them enhanced visibility into the arrival and departure status (and overall timeliness) of buses and trains. This category also includes electronic fare payment systems for public transportation systems, such as Suica in Japan or T-Money in South Korea, which enable transit users to pay fares contactlessly from their smart cards or mobile phones using near field

communications technology.²² Advanced public transportation systems, particularly providing "next bus" or "next train information, are increasingly common worldwide, from Washington, DC, to Paris, Tokyo, Seoul, and elsewhere.

Vehicle-to-infrastructure Integration (VII) and Vehicle-to-vehicle (V2V) Integration

Vehicle-to-infrastructure integration is the archetype for a comprehensively integrated intelligent transportation system. In the United States, the objective of the VII Initiative—as of January 2009 rebranded as IntelliDriveSM—has been to deploy and enable a communications infrastructure that supports vehicle-to-infrastructure, as well as vehicle-to-vehicle, communications for a variety of vehicle safety applications and transportation operations.²³ IntelliDrive envisions that DSRC-enabled tags or sensors, if widely deployed in vehicles, highways, and in roadside or intersection equipment, would enable the core elements of the transportation system to intelligently communicate with one another, delivering a wide range of benefits. For example, IntelliDrive could enable cooperative intersection collision avoidance systems (CICAS) in which two (or more) DSRC-equipped vehicles at an intersection would be in continuous communication either with each other or with roadside devices that could recognize when a collision between the vehicles appeared imminent (based on the vehicles' speeds and trajectories) and would warn the drivers of an impending collision or even communicate directly with the vehicles to brake them.²⁴ IntelliDrive, by combining both vehicle-to-vehicle and vehicle-to-infrastructure integration into a consolidated platform, would enable a number of additional ITS applications, including adaptive signal timing, dynamic re-routing of traffic through variable message signs, lane departure warnings, curve speed warnings, and automatic detection of roadway hazards, such as potholes, or weather-related conditions, such as icing.²⁵

Another application enabled by vehicle-to-infrastructure integration is intelligent speed adaptation (ISA), which aims to assist drivers in keeping within the speed limit by correlating information about the vehicle's position (for example, through GPS) with a digital speed limit map, thus enabling the vehicle to recognize if it is exceeding the posted speed limit.²⁶ The system could either warn the driver to slow down or be designed to

automatically slow the vehicle through automatic intervention. France is currently testing deployment of an ISA system that would automatically slow fast-moving vehicles in extreme weather conditions, such as blizzards or icing.²⁷ The province of Victoria, Australia, is testing a system in which trains could remotely and autonomously brake vehicles attempting to cross their path at railway intersections.²⁸

BENEFITS OF INTELLIGENT TRANSPORTATION SYSTEMS

Applying information technology to a country's transportation network delivers five key classes of benefits by: 1) increasing driver and pedestrian safety, 2) improving the operational performance of the transportation network, particularly by reducing congestion, 3) enhancing personal mobility and convenience, 4) delivering environmental benefits, and 5) boosting productivity and expanding economic and employment growth.

Increasing driver and pedestrian safety

Intelligent transportation systems can deliver important safety benefits. There are 1.2 million fatalities annually on the world's roadways. In 2007, a traffic accident occurred every five seconds in the United States (totaling over 6 million accidents), with a traffic fatality occurring every 13 minutes, killing 41,059 Americans and causing approximately 2.6 million injuries. (In 2008, 5.8 million crashes led to 37,261 fatalities.)²⁹ European Union countries experience a similar number of accidents and fatalities, with 42,943 deaths on European Union roadways in 2006.³⁰ Japan experienced 887,000 traffic accidents in 2006, injuring 1.1 million victims and causing 6,300 fatalities.³¹ A wide range of ITS-based applications—from real-time traffic alerts, to cooperative intersection collision avoidance, to on-vehicle systems such as anti-lock braking, lane departure, collision avoidance, and crash notification systems—have safety as a principle focus. For example, a study of ramp metering in Minneapolis, Minnesota, found that metering reduced total crashes on area roadways between 15 and 50 percent.³² The U.S. IntelliDrive system could potentially address 82 percent of the vehicle crash scenarios involving unimpaired drivers.³³

In fact, intelligent transportation systems are leading to a fundamental rethinking of vehicle safety. Over the

past 50 years, most of the developments in transportation safety—such as the mandatory installation and use of seat belts in the 1970s and the installation of airbags in the 1980s—were designed to protect passengers in the event of a crash. But as Peter Appel, the current Administrator of the U.S. Department of Transportation's (DOT) Research and Innovative Technology Administration (RITA), notes, “All of those technologies assumed there would be a crash. However, much of the work in the next 50 years will be about avoiding the crash altogether and for that [systems like] IntelliDrive have dramatic potential.”³⁴

ITS improve the performance of a country's transportation system by maximizing the capacity of existing infrastructure, reducing to some degree the need to build additional highway capacity.

Improving the operational performance of the transportation network

ITS improve the performance of a country's transportation network by maximizing the capacity of existing infrastructure, reducing the need to build additional highway capacity. Maximizing capacity is crucial because, in almost all countries, increases in vehicle miles traveled dramatically outstrips increases in roadway capacity (and in many countries there is either little more room to build, little political will to build, or both). For example, from 1980 to 2006 in the United States, the total number of miles traveled by automobiles increased 97 percent, but over the same time the total number of highway lane miles grew just 4.4 percent, meaning that over twice the traffic in the United States has been traveling on essentially the same roadway capacity.³⁵

A number of ITS applications contribute to enhancing the operational performance of transportation networks. For example, traffic signal light optimization can improve traffic flow significantly, reducing stops by as much as 40 percent, cutting gas consumption by 10 percent, cutting emissions by 22 percent, and reducing travel time by 25 percent.³⁶ Applying real-time traffic data could improve traffic signal efficiency by 10 percent, saving 1.1 million gallons of gas a day nationally and cutting daily carbon dioxide emissions by 9,600

tons.³⁷ Ramp metering can increase vehicle throughput (the number of cars that pass through a road lane) from 8 to 22 percent and increase speeds on roads from 8 to 60 percent.³⁸ As up to 30 percent of congestion on highways occurs at toll stops, deploying electronic toll collection systems can significantly reduce congestion. Assessing the impact of intelligent transportation systems, including ramp metering, incident management, traffic signal coordination, and arterial access management, a September 2005 Government Accountability Office (GAO) study found that ITS deployments to date had reduced delays in 85 urban areas by 9 percent (336 million hours), leading to a \$5.6 billion reduction in annual costs due to reduced fuel consumption and hours of delay.³⁹

Indeed, reducing traffic congestion is one of the principal benefits of ITS. American commuters spend five days per year (a full work week) stuck in traffic, a total of 4.2 billion hours per year, wasting over 2.8 billion gallons of fuel.⁴⁰ When the impacts on lost productivity, unreliability, cargo delay, and safety are considered, the U.S. Department of Transportation's chief economist concludes that congestion's toll on the U.S. economy amounts to up to \$168 billion each year.⁴¹ In the United States, congestion costs have been growing at 8 percent per year.⁴² Over the next 20 years, the cost of congestion could amount to \$890.5 billion, or 4.3 percent of the value of the entire national economy.⁴³ At current rates, congestion in the United States is expected to become so severe by 2030 that 58 urban areas will have regional congestion levels high enough to qualify as "severe" (up from 28 in 2003).⁴⁴

European Union countries experience 7,500 kilometers of traffic jams every day on their roads, with ten percent of the EU's road network affected by con-

gestion.⁴⁵ In fact, 24 percent of Europeans' driving time is spent in traffic congestion,⁴⁶ at a yearly cost of one percent of the European Union's GDP.⁴⁷ Australia annually suffers \$12.5 billion in costs due to urban congestion. In Japan, congestion costs the nation 3.5 billion man-hours, worth almost ¥11 trillion (\$109 billion) each year.⁴⁸ Deploying intelligent transportation systems has been shown to have a significant and direct impact on reducing congestion. South Korea found that in the initial cities in which it deployed intelligent transportation systems, average vehicle speed increased 20 percent and delay time at critical intersections decreased 39 percent. Experts predict that, in the United States, traffic jams can be reduced as much as 20 percent by 2011 in areas that use ITS.⁴⁹

ITS-enabled variable or congestion pricing can also reduce congestion. According to recent research, a comprehensive pricing approach that incorporates variable pricing tied to travel demand levels (such as congestion pricing) could provide significant congestion benefits. One study estimated that region-wide congestion pricing could reduce peak travel by 8 to 20 percent.⁵⁰ A Brookings Institution study estimated that congestion pricing on the nation's Interstates and other freeways would reduce total vehicle miles traveled by 11 to 19 percent.⁵¹ And a Federal Highway Administration (FHWA) report looking at results from its Value Pricing Pilot Program, which implemented tolling on a number of facilities nationwide, found that even targeted pricing can have a number of effects on driver behavior and traffic volumes, including changes in times, routes, or modes of travel; willingness to pay for faster travel times by traveling on toll lanes; reductions in peak-period traffic volumes; and more-efficient use of highway capacity.⁵²

Figure 2: Three-Dimensional Maps of Time Losses Due to Traffic Congestion in Japan⁵³



ITS also enable transportation agencies to collect the real-time data needed to measure and improve the performance of the transportation system. For example, ITS allow transportation agencies to collect data before and after construction projects to assess their effectiveness in relieving congestion. Japan, for example, uses probe data to create three-dimensional maps showing time loss due to traffic congestion (Figure 2) and fatal accident rates on each section of major highway. Such systems can also be the centerpiece of efforts to reform surface transportation funding systems to hold transportation service providers (for example, state Departments of Transportation) more accountable for providing real results.

ITS can be the centerpiece of efforts to reform surface transportation funding systems to hold transportation service providers more accountable for providing real results.

Enhancing mobility and convenience

ITS enhance driver mobility and convenience by 1) decreasing congestion and maximizing the operational efficiency of the transportation system, as described previously, and 2) providing motorists and mass transit users with real-time traveler information and enhanced route selection and navigation capability. In fact, perhaps the most familiar intelligent transportation systems are telematics-based applications such as satellite-based vehicle navigation or other services that deliver real-time traffic information to drivers either in-vehicle or before departing as they plan for their trip. These services help drivers identify and take the most efficient, trouble-free routes and help preclude motorists from getting lost.

Delivering environmental benefits

Intelligent transportation systems are positioned to deliver environmental benefits by reducing congestion, by enabling traffic to flow more smoothly, by coaching motorists how to drive most efficiently, and by reducing the need to build additional roadways through maximizing the capacity of existing ones. Vehicle transportation is a major cause of greenhouse gas emissions. In England, the transport sector contributes about one-quarter of the country's CO₂ emissions,

93 percent of which comes from road transport.⁵⁴ In France, transport represents 31 percent of final energy consumption and 26.4 percent of greenhouse gas emissions.⁵⁵ Transportation accounts for 25 percent of worldwide greenhouse gas emissions,⁵⁶ and 33 percent in the United States.⁵⁷

Traffic congestion causes an outsized amount of CO₂ emissions. Vehicles traveling at 60 kmph (37 mph) emit 40 percent less carbon emissions than vehicles traveling at 20 kmph (12 mph) and vehicles traveling at 40 kmph (25 mph) emit 20 percent less emissions than the 20 kmph baseline.⁵⁸ One study found that computerized operations of 40 traffic signals in Northern Virginia's Tysons Corner community alone decreased the total annual emissions for carbon monoxide, nitrogen oxides, and volatile oxygen compounds by 135,000 kilograms (and improved fuel consumption by 9 percent).⁵⁹ By 2010, Japan expects to reduce CO₂ emissions by 31 million tons below 2001 levels, with 9 million tons of reduction coming from more fuel efficient vehicles, 11 million tons from improved traffic flow, and 11 million tons from more effective use of vehicles, the latter two a direct benefit of the country's investments in ITS.⁶⁰

"Eco-driving" is an ITS-enabled application that optimizes driving behavior to the benefit of the environment. Vehicles equipped with eco-driving features provide feedback to the motorist on how to operate the vehicle at the most fuel-efficient speeds across all driving situations; the most sophisticated versions give visual or oral instructions on how much pressure to apply to the acceleration pedal. In Japan, Germany, and increasingly the United States, enthusiasts upload records of their driving behavior from vehicles to Web sites where they compete with others to be the most efficient driver.

Thus, intelligent transportation systems that decrease congestion and improve traffic flow ameliorate environmental impact considerably. To be sure, by decreasing congestion and enabling traffic to flow more smoothly, intelligent transportation systems may cause some degree of induced demand, encouraging more drivers to take to the roads due to improved traffic conditions. But while ITS may cause some induced demand, overall it is poised to deliver net environmental benefits.

Boosting productivity, economic, and employment growth

Intelligent transportation systems boost productivity and expand economic and employment growth. By improving the performance of a nation's transportation system, thus ensuring that people and products reach their appointed destinations as quickly and efficiently as possible, ITS can enhance the productivity of a nation's workers and businesses and boost a nation's economic competitiveness. Many transportation agencies already use ITS effectively to reduce traffic congestion and its nearly \$200 billion estimated annual impact on economic productivity and the environment.⁶¹ A 2009 Reason Foundation study found that reducing congestion and increasing travel speeds enough to improve access by 10 percent to key employment, retail, education, and population centers within a region increases regional production of goods and services by one percent. The study reported that achieving "free-flow traffic conditions" (that is, reducing congestion) around key urban and suburban destinations in eight U.S. cities—Atlanta, Charlotte, Dallas, Denver, Detroit, Salt Lake City, the San Francisco Bay Area, and Seattle—could boost the economies in those cities alone by \$135.7 billion and generate close to \$9 billion in new tax revenues.⁶²

ITS deliver other economic benefits as well. They can help mitigate the \$230 billion annual economic impact—equivalent to nearly 2.3 percent of U.S. GDP—of traffic accidents and associated injuries or loss of life. The Eddington Commission in the United Kingdom estimated the effects of congestion pricing on freight and found commercial services industries would be net beneficiaries.⁶³ It also noted that businesses, in particular, accrue significant net gains from road pricing and that these cost savings get passed on to consumers in the form of lower prices.

ITS will also be an important growth industry over the next 25 years. Scholars predict that, over a 20-year horizon (1997 to 2017), the cumulative global market for ITS-related products and services will reach \$420 billion.⁶⁴ A number of countries, including South Korea, Germany, and Japan, view intelligent transportation systems as a key industrial sector, capable of generating considerable export-led economic and employment growth.⁶⁵ The U.S. Department of Transportation has estimated that the field of ITS could create almost

600,000 new jobs over the next 20 years.⁶⁶ A 2009 ITIF study found that a £5 billion investment in intelligent transportation systems in the United Kingdom would support approximately 188,500 new or retained jobs for one year.⁶⁷ Nations that lead in ITS deployment are also likely to be international leaders in ITS job creation and to create economic export and competitiveness advantage for themselves.

The benefit-cost ratio of systems-operations (i.e. intelligent transportation systems) investments has been estimated at about 9 to 1, far above the addition of conventional highway capacity, which has a benefit-cost ratio of 2.7 to 1.

BENEFIT-COST RATIO AND ECONOMIC ASSESSMENTS OF INTELLIGENT TRANSPORTATION SYSTEMS

Overall, the benefit-cost ratio of systems-operations measures (enabled by intelligent transportation systems) has been estimated at about 9 to 1, far above the addition of conventional highway capacity, which has a benefit-cost ratio of 2.7 to 1.⁶⁸ In one study, researchers at Florida International University found that the \$9.9 million annual cost of a traffic operations management system in Broward County, Florida, yielded a benefit of \$142 million in reduced travel time, fuel consumption, emissions, and secondary accidents involving rubber-necks (a 14 to 1 ratio).⁶⁹ With regard to implementation of specific ITS systems, a study of 26 traffic signal optimization projects in Texas found that signal optimization benefits outweighed costs by 38 to 1.⁷⁰

A 2005 study of a model ITS deployment in Tucson, Arizona, consisting of 35 technologies including Highway Advisory Radio, dynamic message signs, a telephone and Web-based traveler information system, and kiosks found the implementation would deliver an expected 6 percent decrease in congestion, a 70 percent decrease in incident-related delay on freeways, and would decrease annual travel time by 7 hours per resident. The environmental impact of the implementation anticipated reduction in annual fuel use by 11 percent and reduction in annual carbon monoxide, hydrocarbon, and nitrous oxide emissions between 10 and 16 percent. The expected average annual cost for

implementing, operating, and maintaining all 35 ITS technologies was estimated at \$72 million, while the expected average benefit from the ITS deployments to mobility, the environment, safety, and other areas was estimated at \$455 million annually. In total, the study estimated that the benefits of deploying ITS outweighed the cost by 6.3 to 1.⁷¹

If the United States were to implement a national real-time traffic information program, the GAO estimates the present value cost of establishing and operating the program would be \$1.2 billion, but would deliver present value benefits of \$30.2 billion, a 25 to 1 benefit-cost ratio.

If the United States were to implement a real-time traffic system management information program in all states and the nation's 50 largest metropolitan areas, the GAO estimates that the present value cost for establishing and operating the program through 2018 would be about \$1.2 billion. However, the present value of total cost savings due to benefits to mobility, the environment, and safety would be about \$30.2 billion, reflecting a \$29 billion benefit.⁷² This works out to a benefit-cost of ratio of 25 to 1 for making real-time traffic information available to U.S. drivers nationwide. The GAO estimates such a system would deliver savings in incident delays of about 321 million hours annually; reduce annual fuel use by 11 percent; and reduce annual carbon monoxide, hydrocarbon, and nitrous oxide emissions between 10 and 16 percent.⁷³

South Korea's implementation of intelligent transportation systems has generated concrete benefits for its citizens. South Korea estimates that the economic benefit of the country's Traffic Management System due to reduced transportation time, accidents, and environmental pollution has been 146.2 billion won (\$109 million) annually. It estimates the impact of its Hi-Pass electronic toll collection system due to reduced transportation time, expense, environmental pollution, and operating expense, including labor costs, as 1,757 billion won (\$1.3 billion), an 11.9 to 1 benefit-cost ratio. Lastly, it estimates the economic benefits of providing real-time traffic information (through in-vehicle

navigation units and the Internet, mobile phone, and radio broadcasts) as 181.1 billion won (\$136 million) annually.⁷⁴

CHALLENGES IN IMPLEMENTING ITS

Given the technical feasibility and significant benefit-cost ratios, why have ITS systems not been deployed more broadly, especially in lagging nations? One reason is that there are a number of challenges involved in developing and deploying intelligent transportation systems. ITS face a range of challenges, including system interdependency, network effect, scale, funding, political, institutional and other challenges. Some challenges are inherent to intelligent transportation systems across all countries; others are specific challenges faced with regard to deploying intelligent transportation systems in the United States.

At the outset, this report provided a taxonomy classifying ITS applications into five categories. But another lens to categorize ITS applications, one more relevant to understanding ITS challenges, is to distinguish between two classes of ITS applications: 1) Those that can be deployed locally on an independent basis and deliver value, and 2) Those that must be deployed as part of a scalable interrelated system to deliver meaningful value. The distinction is useful because many ITS applications are subject to system interdependency challenges, require system coordination to deploy, and must operate at scale to be effective.

In this dichotomy, the first class includes ITS applications such as ramp meters, computerized smart signals, roadside cameras, and even local traffic operations centers. Communities or regions can make independent decisions about whether to fund and deploy ramp meters or adaptive traffic signal lights, and these applications will deliver local benefits to motorists without having to be connected to a scaled system or without travelers having to adopt these technologies at the same time.⁷⁵ (That is, traffic will flow more smoothly if a city or region optimizes its traffic lights or implements ramp metering, as the Minneapolis region experienced.)

But the vast majority of ITS applications—and certainly the ones primed to deliver the most extensive benefits to the transportation network—must operate at scale, often must operate at a national level, and must

involve adoption by the overall system and by individual users at the same time to be effective, raising a set of system interdependency, network effect, and system coordination challenges. ITS applications that must operate at scale include VII and V2V systems, real-time traffic information systems, electronic toll collection systems, and vehicle miles traveled systems.

Many intelligent transportation systems are subject to network effect and scale challenges, thus requiring extensive system coordination—often needed at the national level—to deploy and integrate ITS systems.

For example, real-time traffic information systems are system interdependent. If a region or state makes all its roadways intelligent with real-time traffic data, such efforts do little good if motorists do not have telematics displays in their vehicles (or on mobile phones) to receive and act on that information. Likewise, consumers are unlikely to demand such devices for their vehicles if a large share of communities does not make that real-time traffic information available. VII and V2V systems such as the United States' IntelliDrive initiative also experience network effects. Each additional IntelliDrive-equipped vehicle on the roadway adds value to the network (and over time, each addition to that network has a positive, downward effect on individual systems' marginal costs).⁷⁶ Moreover, VII systems like IntelliDrive must work on a national basis to be truly effective: it does a driver little good to purchase an IntelliDrive-equipped vehicle in Michigan if the system doesn't operate when he or she is driving in Indiana. Likewise, electronic toll collection systems present a far better driver experience when motorists can traverse a country with a single fare payment system, instead of having to acquire multiple passes to pay tolls in differing jurisdictions. The same holds true for vehicle miles traveled systems: it makes little sense for states to independently develop a VMT system because, in addition to requiring a device in the vehicle (ideally as part of the original factory-installed equipment), VMT requires a satellite system and a back-end payment system, and it makes little sense for each state independently to replicate investments in the infra-

structure. Thus, many intelligent transportation systems are subject to network effect and scale challenges, thus requiring extensive system coordination—often needed at the national level—to deploy and integrate ITS systems.

Uncertain marketplaces for intelligent transportation systems may also inhibit their development. In many industries, companies are more than willing to self-fund research and development investments for new products and services, such as new desktop operating systems, software programs, even entirely new jetliners, for which there is a clear customer. But in the case of intelligent transportation systems, companies participating in the industry in some countries may have no clear sense if the customers (principally national, state, or regional transportation agencies) have any money—or appetite—to purchase such systems. ITS development thus entails much higher risk than does development of many other products and services, in part because governments are key buyers, and in some countries, such as the United States, they have shown at best mixed signals as reliable purchasers. Moreover, many government transportation departments barely have enough money to engage in needed maintenance, much less invest in new technologies. At the same time, many are more comfortable investing in concrete than in (silicon) chips. Given that customer interest in ITS may be unclear or uncertain, companies may be understandably reticent to invest in highly risky research and product development of ITS systems.

As discussed subsequently, the United States' federated governance structure for surface transportation creates an inherent challenge to building ITS systems to scale and approaching the transportation system as a nationally integrated network. But travelers don't just drive within state lines; they want to travel across state lines, and they want their ITS applications—whether traffic information systems, toll payment systems, or IntelliDrive systems—to travel with them.

But even with regard to ITS applications that leverage long-established technologies and don't face systemic barriers—such as ramp meters, computerized smart signals, or traffic cameras—many nations, including the United States, under-invest in and insufficiently deploy ITS solutions. This happens, in part, because transpor-

tation funding is often allocated without consideration of performance, giving local and state transportation planners little incentive to give preference to investments that can have maximum impact on optimizing system performance. Part of this is legacy; state and local transportation agencies were created to build and maintain infrastructure, not to manage a transportation network.⁷⁷ Yet combined with bureaucratic inertia and a lack of vision, some government transportation agencies see themselves as “builders of pieces” and not “managers of a system” and place more emphasis on building roads than on ensuring the system functions optimally.

Lastly, ITS face a range of thorny institutional barriers, including jurisdictional challenges, such as which level of government—federal, state, county, city, public authority, or interstate compact—has responsibility for or jurisdiction over ITS deployments.⁷⁸ Organizational challenges include how performing organizations, often across jurisdictions, establish and maintain common plans and schedules; how they allocate funding priorities; and how information is shared.⁷⁹ Other ITS challenges include a lack of expertise within local and regional transportation agencies with regard to the technologies underlying intelligent transportation systems and their implementation. Also, a lack of technical standards for ITS technologies makes it difficult to ensure that systems purchased by different localities can be integrated.⁸⁰

While intelligent transportation systems face a number of challenges, none of them are insurmountable, and indeed many nations have overcome them. Which countries have done so the best, and how, are the subjects to which this report now turns.

METHODOLOGY

Intelligent transportation systems represent such a critical emerging set of IT applications that it is important to identify which countries lead in their development and deployment and to understand why these countries are ahead and why others are lagging. This report seeks to ascertain what the leading countries are doing differently than the lagging countries and to offer recommendations for countries that seek to be leaders in intelligent transportation systems.

Because ITS represent such a broad category of technology and applications, with a number of different countries leading in the deployment or technological development of specific applications, identifying the world’s leaders in ITS requires a holistic assessment that evaluates the evidence and asks, “Which countries’ citizens are benefitting the most from a range of operationally deployed intelligent transportation solutions?” The operationally deployed criterion is crucial because many countries are in the process of field testing or initially deploying intelligent transportation systems, but in many cases these have not yet reached widespread implementation.

ITS development entails much higher risk than does development of many other products and services, in part because governments are key buyers, and in some countries, such as the United States, they have shown at best mixed signals as reliable purchasers.

The scope of this assessment is limited generally to ITS technologies and applications previously enumerated, focusing more on the application of ITS in the road transportation network and for the benefit of motorists. It has not attempted to assess countries’ strengths at electronic freight management or the application of intelligent transportation systems to commercial rail, maritime, or aviation environments.

Our assessment of the world’s ITS leaders was informed by consultations with more than two dozen experts in the intelligent transportation systems field who were asked to rank world leaders in ITS. The research methodology identified the top ten generally recognized leading countries and assessed those countries’ ITS ecosystems to narrow the field to the world’s top three leaders. The analysis uses presentations given and documentation distributed at the 15th ITS World Congress in New York City in November 2008. Additional sources include trade press, market research reports, and the Web sites of the transportation regulatory agencies of many countries.

Most advanced countries are in some way, shape, or form deploying intelligent transportation systems. Ap-

Figure 3: Japan's Vehicle Information and Communications System (VICS)⁸⁵



proximately ten countries are taking moderate to significant steps to deploy ITS applications, including: Australia, France, Germany, Japan, The Netherlands, New Zealand, Sweden, Singapore, South Korea, the United Kingdom, and the United States. (A number of developing countries, notably Brazil, Taiwan, and Thailand are also deploying increasingly sophisticated intelligent transportation systems. China has also committed to making rapid leaps in ITS, and endeavors to become a world leader in the not-too-distant future.)⁸¹ Many of these countries have particular strengths in ITS, notably: real-time traffic information provision in Japan and South Korea; congestion pricing in Sweden, the United Kingdom, and Singapore; vehicle-miles traveled systems in The Netherlands and Germany; electronic toll collection in Japan, Australia, and South Korea; APTS in South Korea, Singapore, and France. But while there is a coterie of leading countries in ITS, several in particular stand out as world leaders: Japan, South Korea, and Singapore. As market research firm ABI Research concurs, “Japan and South Korea lead the world in in-

telligent transportation systems.”⁸² Singapore appears to be in the upper echelon of ITS leadership as well.

ITS is a dynamic space, with countries’ focus on and investment priorities towards ITS shifting quickly. Moreover, ITS technology is rapidly evolving. Many countries have intelligent transportation programs at various stages of research, concept testing, demonstration, or nascent rollout. The report has identified world leaders as of January 2010; countries’ positions may subsequently shift.

THE WORLD LEADERS

Japan

Japan leads the world in intelligent transportation systems based on the importance ascribed to ITS at the highest levels of government, the number of citizens benefitting from use of an impressive range of operationally deployed ITS applications, and the maturity of those applications.

One of Japan's central goals for ITS has been to provide real-time information on traffic conditions on most expressway and arterial roads in Japan. Real-time traffic information can be collected through two primary types of mechanisms: 1) fixed devices or sensors embedded in or beside the roadway, or 2) mobile probes, whether vehicles such as taxis, or mobile devices such as cellular phones which travel in the flow of traffic and have a communications means to report on traffic flow. In collecting and disseminating real-time traffic information, Japan started with a fixed system with its Vehicle Information and Communications System (VICS) launched in 1996. Starting in 2003, Japan began to make extensive use of probes to capture real-time traffic information.

Japan's VICS, the world's first vehicle information communications system, which began service in April 1996 and has been available nationwide since 2003, reduces travel time for long trips by an average of 20 percent.

The story of Japan's ITS world leadership dates back to 1990, when Japan's then-Ministry of Construction (the current Ministry of Land, Infrastructure, Transport and Tourism (MLIT)), Ministry of Internal Affairs and Communications (MIAC), and National Police Agency (NPA), convened to conceive Japan's VICS (Figure 3), an up-to-the-minute, in-vehicle digital data communication system providing traffic information to drivers through their on-board vehicle navigation system.⁸³ The world's first vehicle information communications system began service in Japan in April 1996, and since 2003 the service has been available nationwide.⁸⁴

Japan's VICS takes information collected by Japan's Road Traffic Information Center on roadway conditions, accidents, congestion, and road closures or repairs; processes, edits, and digitizes this information; and then sends it to vehicle navigation systems via three different transmission mechanisms, displaying the data on the driver's car navigation unit in one of three ways: text, simple graphics, or map. Japanese drivers' VICS-enabled on-board car navigation systems dynamically process the VICS data and suggest to the driver op-

timal route guidance to avoid accidents, congestion, weather, and/or roadway hazards. VICS thus provides drivers with in-vehicle, real-time traffic information and can assist the driver in selecting (and plotting) an optimal route to get to his or her destination.⁸⁶

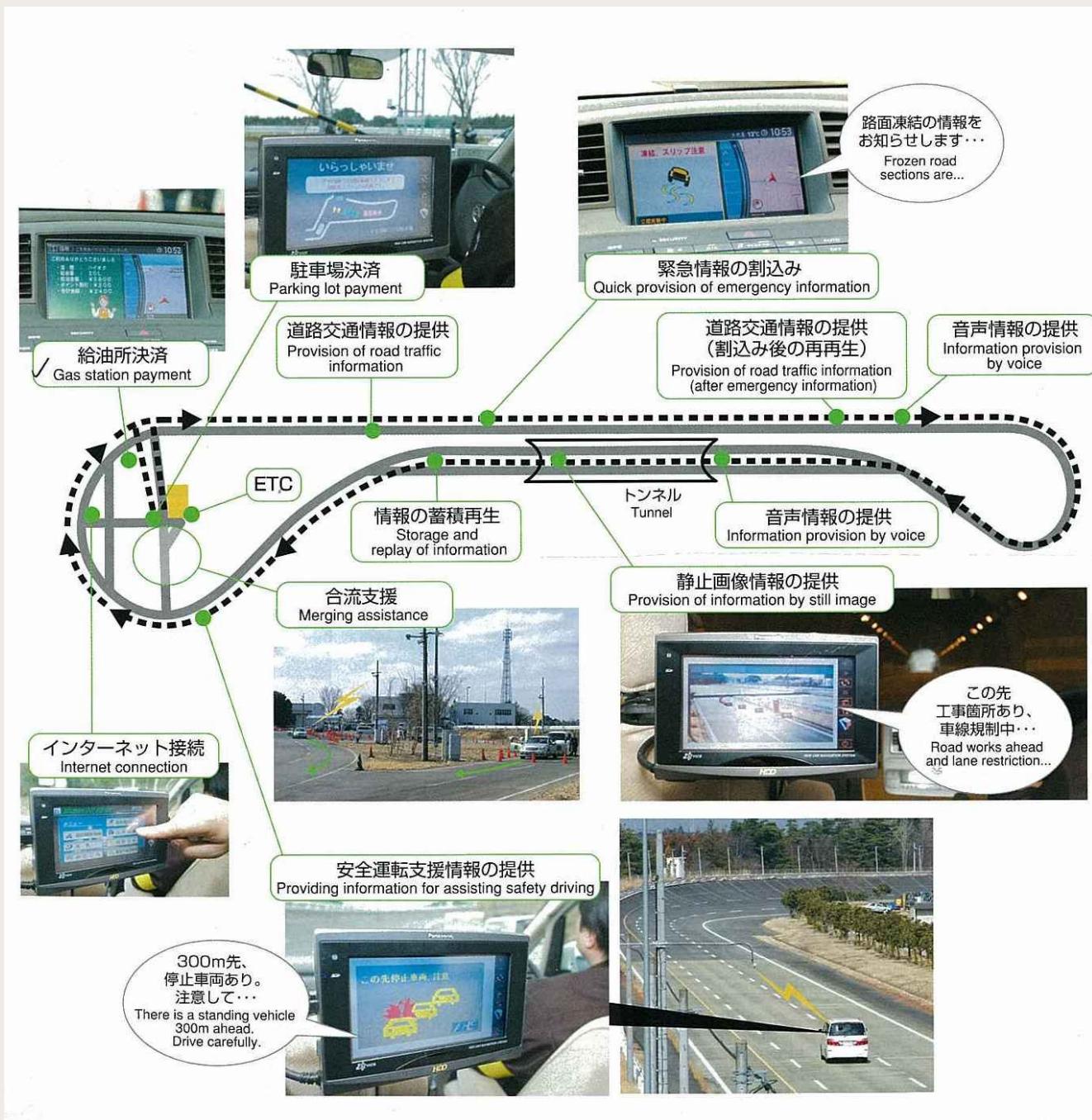
Initially, VICS collected traffic data through sensors embedded in or beside the roadway, traffic cameras, or traffic reports (for example, from police or motorists). But since 2003, traffic and congestion information in Japan has been generated increasingly through the use of probe vehicles, specifically by making VICS-enabled vehicles the probe vehicles themselves. Japan views probe vehicles as "a system for monitoring and collecting data on the precise traffic flow, traffic behavior, positions, vehicle behavior, and weather and natural states by using vehicles as moving traffic-monitoring devices."⁸⁷

VICS information is transmitted to motorists in one of three ways: 1) when a vehicle passes under radio wave beacons, found mainly on Japan's expressways, which provide traffic information for about 200 km in front of the vehicle's position; 2) via infrared beacons, found more often on arterial roadways, which provide VICS information for about 30 km ahead of the vehicle's position; and 3) via FM multiplex broadcasting, which provides wide-area VICS information to prefectural areas. The VICS system uses 5.8GHz DSRC technology.

In Japan, "traffic data is regarded as a key information resource. The role of ministries and relevant organizations set up to manage and supply such information is of key importance."⁸⁸ The VICS Center, which operates the VICS service, is a public-private partnership, chartered specifically as a non-profit organization supported by the National Police Agency, MIAC, and MLIT. However, the VICS Center operates with no governmental funding, and is supported by 90 companies involved in car and vehicle electronic equipment manufacture for ITS.⁸⁹ Real-time traffic information generated by VICS is both made available to the public and made available to be resold by third-party service providers.

Eighty-one percent of VICS customers rate the service as either "essential" or "convenient, if available." Research tests show the VICS service can reduce trav-

Figure 4: Japan's Smartway⁹³



el time for long trips by an average of 20 percent.⁹⁰ At a national level, Japan sees VICS as: 1) providing improved convenience for users, 2) contributing to comfortable lives through an improved environment, enhanced safety, and elimination of lost time, 3) having ripple effects on the industrial economy through increased sales and technological development, and 4) contributing to the development of society. As of December 2008, 23.2 million VICS receivers had been

sold in Japan.⁹¹ Combining that number with other after-market vehicle navigation systems, 33.9 million car navigation units had been sold in Japan as of December 2008.⁹²

As impressive as Japan's VICS has been, it was based on a technical architecture designed in the early 1990s, and thus represents what might be called "Version 1.0" of in-car navigation systems in Japan. Japan is now de-

veloping Smartway (Figure 4), which might be called “Version 2.0” of the country’s state-of-the-art ITS service. Through an on-board unit, Smartway will provide users three classes of services: 1) information and direct driving assistance, including safety aspects, 2) Internet connection services, and 3) cashless payment services at toll booths, parking lots, gas stations, convenience stores, etc. Smartway will also implement advanced technologies such as AHS (Advanced Cruise-Assist Highway System) to eliminate the potential causes of accidents in high-speed environments, and ASV (Advanced Safety Vehicle) to offer safer “smart driving” via vehicle-to-vehicle communications.

Impressively, Smartway evolved from concept development in 2004, to limited deployment in 2007, to initial national deployment in 2010, an extremely fast development timeline.

Smartway will make major advances over the VICS service, particularly by offering traffic information in audio as well as visual format and through its ability to provide locational and contextually specific information to the driver. That is, the system will be able to marry knowledge of the vehicle’s location on the roadway with context-specific traffic flow information, enabling it, for example, to warn the driver, via voice instruction, “You are coming up to a curve with congestion backed up behind it, slow down immediately.” Smartway will also be able to warn drivers when they are coming upon particularly accident prone areas of a roadway. (Twenty-one percent of accidents on Tokyo’s Metropolitan Expressway occur on just 6 percent of its road length, for example.) Also, by using map data stored in the vehicle’s navigation unit, such as data on the radius of curvature or slope angle of a highway, warnings can be given to drivers entering curves at excessive speeds.

Using 5.8GHz DSRC technology, Smartway will also be able to provide visual information of roadway conditions ahead, via actual live camera images of tunnels, bridges, or other frequently congested areas that the driver is about to approach. In addition, the content of nearby dynamic message signs will be provided in audio form. At highway merge points, Smartway will

use a DSRC-enabled roadside unit to alert drivers on the main lanes of the presence of merging vehicles and send appropriate warnings.

Smartway is a collaboration of more than 30 Japanese automobile and vehicle navigation manufacturers. Impressively, Smartway evolved from concept development in 2004 to limited deployment in 2007, an extremely fast development timeline. This success has been attributed in part to a strong systems engineering approach, and also because the effort heavily tapped into academia’s extensive expertise.⁹⁴ Japan intends to begin widespread national Smartway deployment in 2010.

Japanese citizens can also access over the Internet comprehensive real-time traffic and travel information regarding almost all highways in the country through a nationally integrated road traffic information provision system. The Web site features maps (covering most of the country) that display a broad range of traffic information, including forewarning of traffic restrictions, congestion data, road weather information, and road repair activity. Many Japanese access these maps through their mobile phones. Japan has also focused on providing real-time traffic information during natural disasters—particularly earthquakes, landslides, and tsunamis—and has designed mechanisms to automatically feed data about such events into the dynamic message signs on roadways (and, of course, the VICS and Smartway systems).

Japan is also a leader in electronic toll collection, with 25 million vehicles (about 68 percent of all vehicles regularly using Japan’s toll expressways) equipped with ETC on-board units. Japan operates a single national standard for electronic tolling to make the system compatible nationwide for transactions across all the country’s toll roads, unlike in the United States, where one needs multiple tags for different jurisdictions across the country. In designing its ETC technical architecture, Japan adopted an active method for two-way communication based on the 5.8GHz-band system—which enables roadside units and on-board units to interact with each other—instead of a passive method, in which the electronic tag on the vehicle only reacts when “pinged” with a signal from a roadside toll collector device. This design decision has been crucial

Figure 5: Time Losses Due to Traffic Congestion, Nationwide, in Japan



for expanding ETC so private companies can offer automatic toll collection options, such as in private parking garages. Japan also regularly uses variable-toll pricing, easy to implement electronically, to variably price tolls as a means to manage traffic flow and congestion in metropolitan areas.

Aggressively applying ITS to its public transportation system, Japan has begun implementation of a nationwide bus location system. The country defined in March 2006 standard formats for bus information data exchange. While many Japanese cities have implemented real-time bus status updates via Web and mobile platforms, the coverage is not yet nationwide and does not appear to be implemented to the extent that it has been in South Korea and Singapore yet.

Japan uses probe vehicles not only to support provision of real-time traffic information, but also to enable sophisticated administration of road services by monitoring and evaluating the state of transportation system performance and making the results public. For example, by facilitating before and after evaluation of road projects, probe data was able to quantify that a bridge project in Niigata city reduced congestion by 25,900 hours, saving ¥106 million. Using information technology, Japan enhances the accountability of its road administrators by illustrating the effect of road construction and improvement projects in addressing

traffic congestion with three-dimensional maps of traffic congestion using data on traffic volume and travel time collected from probe cars (Figure 5).

South Korea

South Korea's strengths in several ITS application areas make it a world leader in intelligent transportation systems. These strengths include: 1) real-time traffic information provision, 2) advanced public transportation information systems, and 3) electronic fare payment and electronic toll collection. This section provides a brief background on the history of ITS deployment in South Korea and then analyzes current conditions.

ITS has been a national priority of South Korea since the late-1990s, when, recognizing the need to bring intelligence to its transportation system, South Korea built the country's legal and institutional supports for ITS with the formulation of its first national ITS master plan in 1997 and passage of the 1999 Transport System Efficiency Act, together which set ITS standards, developed an ITS technical architecture, and specified a regional and supra-regional implementation plan.⁹⁵ South Korea charged the Ministry of Construction and Transportation (MOCT) with spearheading ITS development. In December 2000, South Korea unveiled its National ITS Master Plan for the 21st century, a 20-year blueprint for ITS development in South Korea that provided a strategic guideline for development of seven specific ITS application areas as part of a National ITS Service (Figure 6), along with time schedules and budgets.⁹⁶ The National ITS Service addresses: traffic operations and management, electronic payments, information integration and dissemination, public transport quality enhancement, enhanced safety and automated driving, efficient commercial vehicles, and pollution control.⁹⁷ A central mission of the National ITS Service is to create a network of traffic systems that facilitate interactions and interconnection between South Korea's large cities.

The ITS Master Plan identified three phases of ITS development in Korea (Table 2). It articulated a budget for the development of the seven core ITS services over each of the three development phases through 2020, originally estimating a cost for the entire plan of 8.34 trillion Korean won (\$6.67 billion).⁹⁸ These investments were to be funded with contributions from the central government, local governments, and the

Figure 6: South Korea's National ITS Service



private sector. As of 2007, South Korea updated its investment schedule, committing to invest a total of \$3.2 billion from 2007 to 2020 (an average of \$230 million annually over the 14-year period) in intelligent transportation systems.

South Korea built its ITS infrastructure on a city-by-city basis, establishing “ITS Model Cities” starting in 1998 with a pilot in Kwa-chon city, followed by a 90.8 billion won (\$75 million) MOCT investment to set up three more model cities (in Daejon, Jeonju, and Jeju) from 2000 to 2002 to develop standards for ITS architecture and implementation.⁹⁹ Through providing 1) adaptive signal control, 2) real-time traffic information, 3) public transportation management, and 4) speed violation enforcement in these model cities, travel speed increased an average of 20.3 percent and critical inter-

section delay time reduced an average of 39 percent.¹⁰⁰ With these initial pilots validating ITS benefits, the South Korean government provided national budget support to introduce ITS systems in 25 more South Korean cities by 2007. These 29 cities are part of South Korea’s Ubiquitous Cities initiative, which endeavors to embody information technology throughout all city services—from traffic services including city traffic and navigation information to public services including government, firefighting, and police—and to enable citizens to access and utilize them at anytime, anywhere, and from any device through a unified platform.

South Korea’s Expressway Traffic Management System (ETMS) collects real-time traffic information through three primary mechanisms: 1) vehicle de-

Table 2: Phases of ITS Development in South Korea

<i>Project phase</i>		<i>Tasks</i>	<i>Details works</i>
Phase I	2001–2005	Launch project, with fundamental infrastructural works and services	Phase I
Phase II	2006–2010	Growth and expansion	Phase II
Phase III	2011–2020	Maturation and advancement	Phase III

Source: ITS Korea (2005).

Figure 7: Seoul's Bus Information System



tection systems (VDS), which are installed inductive loops within expressways at intervals of 1 km that detect information such as traffic volume and speed, 2) closed-circuit cameras deployed every 2 to 3 km, and 3) vehicle probe data. This data is communicated to South Korea's National Transport Information Center (NTIC) via a very high-speed optical telecommunication network deployed to support the country's ITS applications (including also South Korea's Hi-Pass electronic toll collection and electronic fare payment systems).¹⁰¹ The NTIC, South Korea's integrated traffic information service, aggregates data from 79 different transport authorities.

Collected and processed traffic information is provided to South Korean citizens free of charge through various channels including Vehicle Message Signs, Automatic Response Service, the Internet, and broadcasting.¹⁰² The NTIC Web site offers an interactive graphic map that citizens can access to see a consolidated view of traffic flow status on the country's roadways. South Korea also broadcasts traffic information on the Traffic Broadcasting Station, a special broadcasting station for providing traffic information including live announcements, closed-circuit television images, text messages, and sound broadcasting 24 hours a day. Apart from making traffic information on Korean expressways

Figure 8: South Korea Hi-Pass Card and OBU Device



publicly available, in February 2008 the government designated the Korea Expressway Corporation (KEC), which constructs and manages South Korea's expressways, as the corporation for provision of integrated traffic information not only on expressways but also on national roads and urban district roads. KEC offers paid traffic information services through mobile phones, telematics devices, satellite broadcasting, and IPTV. Of the 16 million vehicles in South Korea, 5 million (31 percent) use on-board vehicle navigation systems.¹⁰³

Public transportation information systems, particularly for buses, are also highly deployed in South Korea. Seoul alone has 9,300 on-bus units, equipped with wireless modems and GPS position detectors (Figure 7). Three hundred bus stops communicate with Seoul's central traffic operations management center via wireless communications to provide an integrated, up-to-the second view of Seoul's bus transportation network. The service includes bus arrival time, current bus location, and system statistics. Bus stop terminals are equipped with LCD or LED message screens to alert riders to bus status and schedules. South Koreans regularly use the location-based tracking feature in their GPS-enabled phones to access a Web site that automatically presents a list of available public transportation options (bus or subway); the system recognizes where in a city the passenger is located and presents walking directions to the nearest public transportation option.

South Korea has introduced a unified fare smart card system for public transportation called T-money (initially available only in Seoul but now being ex-

panded nationally). The Korea Smart Card Company, a joint venture spearheaded by The Seoul Metropolitan Government and including LG Group (an electronics company), credit card companies, and smaller telecommunications companies, launched T-money in 2004.¹⁰⁴ Customers use T-money to pay for transportation, including bus, train, and taxi service, as e-money to make purchases at vending machines, convenience stores, and museums, to pay fines or taxes, and even as a mileage or membership card. As of March 2009, customers used T-money for 30 million public transit transactions per day (15.4 million bus and 14.6 million subway transactions). Within the Seoul metropolitan area, 18 million T-money smart cards have been issued, with T-money accepted at the reader terminals of 19,750 buses; over 8,000 subway terminals; 73,000 taxi cabs; 21,000 vending machines; and 8,300 convenience stores, fast food stores, and parking garages. As Seoul's subway system has moved from paper tickets to smart cards, it has eliminated the need for 450 million paper magnetic stripe tickets at a savings of 3 billion won (\$2.4 million) per year. Installation of electronic payment systems on mass transit vehicles is expected to be completed by the end of 2011.¹⁰⁵

South Korea's Hi-Pass electronic toll collection system (Figure 8), which uses 5.8GHz DSRC technology to enable non-stop cashless toll payment, covers 260 toll plazas and over 3,200 km of highway in South Korea. Five million South Korean vehicles use Hi-Pass, which has a highway utilization rate over 30 percent. South Koreans can also use their Hi-Pass card for other purchases beyond highway tolls, including at parking lots, gas stations, and convenience stores.

Figure 9: Singapore's Traffic Operations Management Center



Figure 10: Real-Time Public Transport Status Information at Singapore Bus Stop



SINGAPORE

Singapore is a world leader in intelligent transportation systems based on its: 1) use of probe vehicles to collect traffic information, 2) use of electronic road pricing (that is, congestion charging), 3) nationwide deployment of adaptive computerized traffic signals, 4) and use of traffic management ITS applications.

Singapore's Land Transport Authority (LTA) has responsibility for all modes of transportation in the country and oversees implementation of intelligent transportation systems in Singapore.¹⁰⁶ The country's

ITS Master Plan envisions “an optimized and efficient land transport network leveraging ITS to enhance commuters’ travelling experience.”¹⁰⁷ The three strategic thrusts of Singapore’s ITS Master Plan include: 1) deploying and integrating ITS across Singapore, 2) developing partnerships between the private sector and government agencies (as well as other stakeholders), and 3) viewing ITS as a platform for industry development.¹⁰⁸

Singapore collects real-time traffic information through a fleet of 5,000 taxis which act as vehicle probes, feed-

Figure 11: Singapore Parking Guidance System



ing their speed and location information back to Singapore's Traffic Operations Management Center (Figure 9), enabling it to generate an accurate picture of traffic flow and congestion on Singapore's roadways from this critical mass of probe data. The arrangement Singapore has with taxi operators is a commercial one. It developed when one of Singapore's dominant taxi operators decided to enhance their operations with a GPS fleet management and dispatch system, and the Land Transport Authority asked if it could ride on this development to obtain traffic information.¹⁰⁹ Singapore disseminates traffic information via its Expressway Monitoring and Advisory System (EMAS), comprised of variable message signs placed strategically along its expressways. In addition, Singapore purchases air time from radio service providers to transmit traffic updates over the air. Singapore is also starting to implement these traffic messaging systems on its arterial roadways.

Singapore is a world leader in electronic road pricing, and has actually had some form of congestion pricing scheme in place in its city center since 1975, although initially the system was based on license sheets in windscreens and spot-check police enforcement. In 1998, Singapore implemented a fully automated electronic road pricing (ERP) system that uses DSRC with an in-vehicle unit installed in each car that accepts a prepaid stored-value smart card called the "Cashcard." The cost of using a particular road is automatically deducted from the Cashcard when the vehicle passes an ERP gantry. The system has since been expanded beyond Singapore's downtown Restricted Zone to its expressway and arterial roadways, and now accepts credit card payment. Singapore's ERP scheme actually uses traffic speeds as a proxy for congestion. Rates are raised or lowered to achieve traffic optimization along a speed-flow curve, 45 to 65 kmph for expressways and 20 to 30 kmph for arterial roads. In effect, the system uses market signals to manage supply and demand on Singapore's roadways. Singapore is currently evaluating moving to a next generation ERP system (ERP II) that would use satellite-based GPS technology to make distance-based congestion charging possible. Singapore believes that converting to GPS-based technology will enable a flexible and more efficient method to manage congestion, and provide opportunities to develop a more intelligent information dissemination and navigation system for drivers.¹¹⁰ LTA estimates

that the economic benefit of time savings due to shorter delays on expressways, largely achieved through use of congestion charging, amounts to at least \$40 million annually in Singapore.¹¹¹

Singapore has made public transportation a more attractive option for commuters by installing real-time bus arrival panels in January 2008 at almost all bus stops throughout the country (Figure 10).¹¹² As of March 2010, LTA will begin disseminating real-time bus arrival information to all bus stops island-wide via various mobile platforms. In July 2008, LTA launched a Public Transport Journey planner with basic map features that advises commuters on optimal public transport travel routes from origin to destination. This will be followed by an Integrated Multi-Modal Travel Information System (IMTI), which will provide commuters with comprehensive travel information on different platforms such as the mobile phone and the Internet (via GRPS, WAP, and WIFI).¹¹³

In April 2008, Singapore launched a Parking Guidance System (Figure 11), consisting of roadside variable messaging signs, which alerts drivers to the location of public parking locations throughout the city and how many spots are available at each location. Singapore is now expanding this service country-wide.

Singapore's long-term ITS plans include advanced telematics that will bring location-based services and traffic information to commuters through in-vehicle devices, and advanced congestion management systems that will include both targeted and variable user road-charging schemes. Singapore is at the cutting edge of predictive traffic flow modeling based on using historic and real-time traffic data.

INTELLIGENT TRANSPORTATION SYSTEMS IN THE UNITED STATES

In contrast to Japan, South Korea, and Singapore, the United States lags world leaders in aggregate ITS deployment, particularly with regard to provision of real-time traffic information by government transportation agencies, progress on vehicle-to-infrastructure and vehicle-to-vehicle integration, adoption of computerized traffic signals, and maximizing the effectiveness of its already-installed ITS systems. To be sure, the United States has pockets of strengths with regard to ITS in particular regions and applications, including

use of variable rate highway tolling, electronic toll collection, certain advanced traffic management systems such as ramp metering, and an active private sector market in telematics and travel information provision, but the United States is not quite at the vanguard of the most elite countries deploying ITS. Implementation of intelligent transportation systems in the United States varies immensely by state and region, thus tending to be sporadic, isolated, incremental, and, unlike Japan's Smartway, not connected into a nationally integrated intelligent transportation system.

Implementation of ITS in the United States varies immensely by state and region, thus tending to be sporadic, isolated, and, unlike Japan's Smartway, not connected into a nationally integrated intelligent transportation system.

This is not a reflection on the technology or the promise of ITS, nor it is a reflection of the organizations at the state and federal levels responsible for ITS deployment. Rather, as discussed subsequently, it is the result of a continued lack of adequate funding for ITS and the lack of the right organizational system to drive ITS in the United States, particularly the lack of a federally-led approach, as opposed to the “every state on its own approach” that has prevailed to date. Recognizing the need to reorganize and reanimate the United States’ approach to intelligent transportation systems, on January 8, 2010, the Research and Innovative Technology Administration within the U.S. DOT unveiled a new “ITS Strategic Research Plan, 2010-2014.”¹¹⁴ The Plan charts an ITS research portfolio that will “continue efforts necessary for researching, prototyping, testing, evaluating, and transferring the next generation of ITS technology.”¹¹⁵ Moreover, it elucidates a framework for research questions regarding ITS technology, applications, and policy that seeks to make, by 2014, an assessment of the feasibility, viability, and value of deploying fully integrated VII and V2V platforms such as IntelliDrive. While this research work is important, and the creation of an ITS research plan for the United States marks a credible step forward, it is not enough. The U.S. Department of Transportation needs to make a fundamental shift from a focus solely on ITS research to include a much greater focus on ITS deployment, and significantly accelerate the speed with which ITS technologies reach the U.S. traveling public.

History of ITS Policy Development in the United States

Federal activity regarding ITS began with The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, which established a federal program to research, develop, and operationally test intelligent transportation systems and to promote their implementation. The program began as a three-pronged effort that fostered the development of ITS through: 1) basic research and development, 2) operational tests that served as the bridge between basic research and full deployment, and 3) various deployment support activities that facilitated the implementation of integrated ITS technologies.¹¹⁶ ISTEA originally authorized \$659 million to ITS for fiscal years 1992 to 1997, with additional funds appropriated for a total of approximately \$1.2 billion. The Transportation Efficiency Act for the 21st Century (TEA-21), passed in 1998, authorized a similar amount (\$1.3 billion) through fiscal year 2003.

In 2005, Congress enacted the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). SAFETEA-LU ended the ITS Deployment Program at the close of fiscal year 2005, but continued ITS research at \$110 million annually through fiscal year 2009.¹¹⁷ Since ending the ITS Deployment Program, the federal ITS effort has been much more focused on a research than a deployment role. The U.S. Department of Transportation estimates that states and localities annually invest \$500 million to \$1 billion in ITS projects in the United States.¹¹⁸

A corporate style “board of directors”—the ITS Management Council—develops and directs federal ITS policy. As of May 2006, the Administrator of RITA within the U.S. Department of Transportation took responsibility for the strategic direction and management oversight of DOT’s ITS program. Activity is coordinated through the ITS Joint Program Office (JPO), which is comprised of program managers and coordinators of DOT’s multimodal ITS initiatives.

DOT’s ITS program focuses on intelligent vehicles, intelligent infrastructure, and the creation of an intelligent transportation system through integration with and between these two components. The federal ITS effort in the United States focuses on nine initiatives: 1) IntelliDrive (the successor to the VII initiative); 2) Next-generation 9-1-1; 3) Cooperative Intersection Collision Avoidance; 4) Integrated Vehicle Based

Safety Systems; 5) Integrated Corridor Management Systems; 6) Clarus (roadside weather condition monitoring); 7) Emergency Transportation Operations; 8) Mobility Services for all Americans; and 9) Electronic Freight Management.

Provision of Real-Time Traffic Information to Drivers

One area in which the United States notably trails Japan and other world leaders is in the provision of publicly available, real-time traffic information to citizens. Recognizing that real-time traffic information systems, like other forms of ITS, can be used to improve traffic flow and congestion, Congress enacted legislation in 2005 requiring the U.S. Department of Transportation to establish the Real-Time System Management Information Program, in order to provide states the capability to monitor traffic and travel conditions on major highways and share that information.¹¹⁹ To establish the Program, the Federal Highway Administration issued a rule proposing requirements for states to make available certain traffic information, specifically travel time, travel speed, and incident notification, on major highways, and to meet data quality standards, including standards for timeliness, accuracy, and availability of that traffic information.

In November 2009, the Government Accountability Office, at the request of the House Committee on Transportation and Infrastructure, issued a report, “Efforts to Address Highway Congestion through Real-Time Traffic Information Systems are Expanding but Face Implementation Challenges” which, using 2007 data, found shortcomings in states’ abilities to accrue and provide real-time traffic information to the public. State and local agencies distribute real-time traffic information to the public primarily through the Internet, e-mail, television and radio, dynamic message signs, Highway Advisory Radio, and a 511 Travel Information System.¹²⁰ The GAO report found that

while coverage provided by these services and technologies is expanding, there are gaps in coverage and variations in aspects of real-time traffic information, such as the quality of the data collected and the extent to which state and local agencies share their data.¹²¹

Regarding the collection of real-time traffic information, the report found that technologies used by state and local agencies to do so covered only 39 percent of the combined freeway miles in 64 metropolitan areas providing information.¹²² The GAO noted that, while that percentage was up 6 percent from the 33 percent coverage available in 2004, it remained a significant gap, given that urban freeways account for the majority of the nation’s traffic, congestion, and travel time variability.¹²³

The picture was not much better with regard to the dissemination of real-time travel information to the public. The GAO report found that, in 2007, the percentage of the (94 data-providing) U.S. metropolitan areas delivering real-time highway travel time and highway travel speed information to the public was, respectively, 36 percent and 32 percent (Table 3).¹²⁴ The situation was worse with regard to arterial roadways, for which only 16 percent of the (102 data-providing) U.S. metropolitan areas disseminate real-time travel speed information and only 19 percent distribute travel time data in real-time. The United States does do better with distributing incident information in real-time, with 87 percent of metropolitan areas distributing real-time information about incidents on freeways and 68 percent sharing incident information on arterial roadways.¹²⁵

With regard to the 511 Traveler Information Service, which provides a three-digit telephone number that travelers can call via telephone (using an interactive voice response automated system) to obtain various types of travel information, including information on

Table 3: Percentage of Metropolitan Areas in Which Incident, Travel Time, and Travel Speed Information Were Disseminated to the U.S. Public in 2007

Type of Information	Percentage of metropolitan areas	
	Freeways	Arterial roads
Incident	87%	68%
Travel time	36%	19%
Travel speed	32%	16%

traffic and road conditions, as of September 2009 the system operates in 36 states and is available to 181 million Americans (60 percent of the population). But the GAO found that many states, such as Alaska, Louisiana, Massachusetts, and Missouri, do not transfer calls, transfer data, or share databases. While the report found that 23 state and metropolitan/regional areas do transfer calls from one 511 system to another 511 system, amazingly the report found that no states actually transfer 511 data. That is, between no states are the underlying data systems accessible to other 511 systems, which would have enabled those systems to exchange information with neighboring systems via computer networks without having to manually transfer phone calls.¹²⁷ The main reason the states do not share data is that they do not want to incur the cost of matching data or developing a matching database for two or more systems. Moreover, only nine states and metropolitan/regional areas used the same underlying application or database to share their 511 systems. (One success case is the I-95 Corridor Coalition, stretching from Maine to Florida, which provides information via a common Web site on traffic conditions and travel time on I-95.)

The GAO's report noted that the key traffic data collection technology used by many public agencies—fixed sensors embedded in roadways—generally produces reliable information, but is prone to failure. For example, in California, some districts have traffic sensors that only function 50 percent of the time (due to hardware failure, such as broken wiring and missing parts) seriously jeopardizing the ability of these systems to collect and distribute real-time information to the public.¹²⁸

One reason the United States trails world leaders in providing real-time traffic information is the result of a real-time traffic information collection and dissemination program created and implemented from the late-1990s to the mid-2000s that lacked proper oversight and that in some cases left control of the data (or determination of its use) in the hands of a private provider.

In 1998, the TEA-21 transportation authorization legislation authorized an “intelligent transportation infrastructure program” for the “measurement of various transportation activities.” The legislation speci-

fied that the program would provide data from an expanded “infrastructure of the measurement of various transportation system metrics” in more than 40 metropolitan areas at a cost of \$2 million each “utilizing an advanced information system designed and monitored by an entity with experience with the Department of Transportation.”¹²⁹ The legislation was included as an earmark—a grant that specifies in detail not just the purpose and amount of the grant, but who shall receive the money and under what terms—and the specified “entity with experience with the Department of Transportation” was the firm Traffic.com. The “preselected” firm, Traffic.com, was thus made the sole source provider of traffic information for cities participating in the program.

The need remains for the United States to develop an integrated strategy to ensure that the vast majority of U.S. citizens have access to real-time traffic information.

While TEA-21 authorized the program, appropriations (funding) for the program came from the FY 2002 defense authorization bill, which earmarked \$50 million in funds to implement solar-powered traffic sensors in roads and highways to collect traffic information in 25 metropolitan areas, with a \$2 million federal grant to each of the 25 metropolitan areas. The program was renamed the Transportation Technology Innovation and Development (TTID) initiative. However, the money came with a catch: It could only be used by transportation agencies to hire Traffic.com.¹³⁰ From 2002 to 2004, state and local agencies representing 14 cities—including Washington, DC, Boston, Chicago, San Francisco, and Detroit—signed up to participate in the program, generally under terms stating that the U.S. Department of Transportation would cover 80 percent of the project, and the state or local agency would cover 20 percent of the cost (\$500,000 out of a \$2,500,000 implementation.)

As an article in the Fall 2008 issue of *Regulation* magazine noted, the terms of the agreements that state and local transportation agencies were compelled to sign with Traffic.com (in order to access the federal funds) considerably favored Traffic.com in several ways at the expense of competing traveler/traffic information

companies, the local public-sector agency partner in each of the program's cities, and the general public.¹³¹ For example, the agreements generally prevented the local public-sector partner from providing valuable traveler information to the public. The agreements usually restricted local agencies to only using the most valuable Traffic.com-generated data internally, thus preventing agencies from providing travel times computed from the data on variable message signs or in their 511 telephone traffic services. In effect, the terms meant that, in many cases, the local public-sector partner could not use publicly subsidized data to provide information about traffic conditions to the traveling public.¹³² In fact, in several instances, transportation agencies had to pay Traffic.com to receive traffic data generated from taxpayer-paid devices that Traffic.com installed.¹³³ Moreover, the authorizing federal legislation effectively gave Traffic.com the power to exclusively set the terms—including the price—for sale of the data outside local agencies, even though it was dealing in many cases with direct competitors in the commercial traveler information business.¹³⁴

In some cases, the agreements have had a direct impact on constraining state's efforts to get real-time traffic information to motorists on a timely and cost-efficient basis. For example, according to a May 2007 FHWA report entitled, "Real-Time Traveler Information Services Business Models: State of the Practice Review," in Chicago, Illinois, the Illinois State Toll Highway Authority (the TTID local agency partner) found that it could not access Traffic.com's publicly subsidized but privately controlled traffic data. The report found, "Some agencies who entered into Intelligent Transportation Infrastructure Program (ITIP) contracts in order to take advantage of external funding to kick-start or otherwise enhance its traveler information program have found the restrictions on the ITIP data limiting. In the case of the Illinois Tollway, for instance, the ITIP agreement prohibited the posting of ITIP travel times on the agency's DMS. In response, the Tollway developed a program to calculate its own travel times, without the ITIP sensors. As a result, the travel times on the DMS and the Traffic.com Web site would differ slightly."¹³⁵ In effect, the Illinois Tollway was contractually prohibited from using taxpayer-subsidized data to compute travel times for display on their own dynamic message signs (DMS) and had to find an alternate method to do so generating additional costs for taxpayers.¹³⁶

The experience with the TTID program is a reminder that taxpayer-funded initiatives to generate real-time traffic information are valuable and necessary, but they should make the real-time traffic information generated freely available to the traveling public. In fact, the need remains for the United States to develop an integrated strategy to ensure that the vast majority of U.S. citizens have access to real-time traffic information. Indeed, the GAO report found 17 of 19 experts interviewed agreeing that a need exists for the development of a nationwide real-time traffic information system.¹³⁷ They argued that current approaches to developing real-time traffic information systems are fragmented because currently state and local transportation agencies generally develop and use these systems only within their own jurisdictions, leading to gaps in coverage and inconsistencies in the quality and types of data collected.¹³⁸

A U.S. strategy to get real-time traffic information to drivers will need to both leverage the capability of mobile phones and portable navigation devices to serve as probes and the competencies of private sector players to partner with public agencies to collect and disseminate real-time traffic information. For example, whereas in 2007 only 28 million portable navigation devices, from companies such as TomTom, Garmin, and Navman, were used by U.S. motorists, that number is expected to climb to 50 million by 2015. Meanwhile, the number of GPS-enabled mobile phones used by U.S. mobile subscribers is expected to increase from 22 million in 2007 to 380 million phones by 2015.¹³⁹ This has the potential to transform how traffic data is collected and consumed in the United States. Already by May 2007, 7.5 percent of U.S. mobile subscribers were accessing navigation mapping information via their mobile phones.¹⁴⁰

Traffic information provider INRIX, leveraging both commercial fleet vehicle probes and applications installed on iPhone and Android GPS-capable mobile phones to turn them into mobile probes, asserts that it has reached real-time traffic coverage for more than 260,000 miles in North America, via 1.5 million vehicles and devices it has enrolled in its Smart Drivers Network.¹⁴¹ Competitor NAVTEQ provides traffic data available in more than 120 markets across the United States.¹⁴² Berkeley University's Mobile Century experiment has demonstrated that GPS-enabled cell phones can be used as sensors for traffic monitoring

purposes while preserving individuals' privacy when collecting data.¹⁴³ DOT has a program, Safe-Trip 21, that is testing the use of vehicle probes to generate real-time traffic data, but it appears the private marketplace is more quickly validating mobile phones-as-probes technology and proving there is ready demand in the marketplace for such services.

Vehicle Infrastructure Integration in the United States

Over the past 15 years, a primary focus of U.S. ITS policy has been an initiative initially called Vehicle Infrastructure Integration (VII). The objective of the VII initiative was to deploy and enable a communications infrastructure that supports vehicle-to-infrastructure, as well as vehicle-to-vehicle, communications for a variety of vehicle safety applications and transportation operations.¹⁴⁴ Despite more than 15 years of research and testing, but with VII still far from operational deployment, at the end of 2007 the U.S. Department of Transportation announced the VII program would undergo a full reassessment. The Department of Transportation opened up every aspect of the VII program—from providers, technologies, and wireless communications methods, to business models and public-private partnerships—for reevaluation, issuing a wide ranging request for information to solicit input from interested stakeholders on these issues.

The agency decided to reframe the VII approach from the originally envisioned, all-encompassing “all and everywhere” nationwide rollout approach to one marked by incremental deployments that lean towards ‘near-term’ quick-win technologies and applications.¹⁴⁵ The new approach would place increased emphasis on the involvement of the aftermarket sector and bring multimodality (integration across transportation modes) to the fore. A focus of the 2007 VII program review was revisiting a series of decisions that had effectively excluded the after-market sector from the VII scene. Given that it takes at least 14 years (and often several decades) for a country’s vehicle population to refresh, intelligent transportation solutions have to be designed that not only work with newer vehicles but can also be retrofitted to older vehicles so as not to exclude a significant portion of drivers (especially the socially or economically disadvantaged) from participating in VII’s benefits. This had been a criticism raised even by the supporters of the VII initiative in its original form.

The review of the United States’ vehicle infrastructure integration program culminated in a decision on January 9, 2009, to rebrand the VII initiative under the new moniker IntelliDrive.¹⁴⁶ On January 10, 2010, RITA announced a new ITS Strategic Plan, a five-year plan to achieve a national, multi-modal surface transportation system that features a connected transportation environment among vehicles, the infrastructure, and portable devices that leverages wireless communications technology to maximize safety, mobility, and environmental performance. At the core of the ITS Strategic Plan will be IntelliDrive, a suite of technologies and applications that use wireless communications to provide connectivity: 1) with and between vehicles of all types, 2) between vehicles and roadway infrastructure, and 3) between vehicles, infrastructure, and wireless consumer devices. In announcing the ITS Strategic Plan, the JPO made an important decision to move forward with DSRC at the 5.9GHz spectrum as the standard for wireless connectivity for IntelliDrive. (This puts the United States in-line with Japan, South Korea, and most European countries, which have also elected to use DSRC wireless technology in their intelligent transportation systems.) The ITS Strategic Plan essentially articulates a five-year research plan to ascertain the technical feasibility of IntelliDrive, the value of such a system, its policy and safety ramifications, and to make a go/no-go decision by 2014 on moving forward with a national deployment of IntelliDrive.

Maximizing Value from Existing ITS Platforms

Another area the United States has opportunity for improvement regarding ITS is in maximizing the value of already-deployed ITS systems and taking advantage of readily available and implementable ITS applications and technologies, such as adaptive traffic signal lights. For example, in 2007, The National Transportation Operations Center (NOTC) National Traffic Center Report Card gave the United States a “D” grade because the vast majority of the then-272,000 signalized intersections in the United States were using static, outdated timing plans based on data collected years or decades before.¹⁴⁷

The U.S. Department of Transportation announced in 1996 a goal that 75 of the nation’s largest metropolitan areas would have a complete intelligent transportation infrastructure by 2005.¹⁴⁸ A 2005 Government Accountability Office report found that, by 2004, 62

of the 75 U.S. metropolitan areas had met the DOT “goal” of deploying integrated ITS infrastructure. However, GAO’s report noted that that DOT’s criteria set “relatively low thresholds of ITS infrastructure—such as 20 percent of freeway miles and 33 percent of signalized intersections covered by certain ITS technologies.” Moreover, the report found that communities were not enjoying many of the potential benefits from deployed intelligent transportation systems because their operations were underfunded and not performing to capacity. For example, the report noted that Chicago had built ten traffic management centers, but because of funding constraints, six of the ten lacked staff dedicated to monitoring traffic conditions on a regular basis, compromising their potential traffic and congestion mitigation benefits.¹⁴⁹ In another example, the study found the San Francisco Bay Area had 4,700 traffic sensing detectors across its 2,800 freeway miles in 2003, with 29 percent of the roadways featuring sensoring devices spaced every one mile, and 40 percent with sensors spaced every two miles. However, about 45 percent of the devices were out of service (lacking funds for maintenance or break-fix), significantly reducing the system’s ability to produce reliable traffic data.¹⁵⁰ GAO’s 2009 report on real-time traffic information confirmed that these problems persist and in some cases have not improved appreciably since 2005.

The GAO found “several barriers that limit the widespread deployment” of ITS at the state, regional, and local level in the United States. The study noted that state and local transportation officials often view other transportation investment options, such as adding a new lane to a highway, more favorably than ITS when deciding how to spend limited transportation funds.¹⁵¹ Moreover, the GAO found that, unfortunately, “information on benefits does not have a decisive impact on the final investment decisions made by state and local officials.” This challenge is amplified as elected officials often find ITS investments less appealing than highway construction. The GAO study quoted Chicago- and San Francisco-area transportation officials lamenting that since ITS applications, “do not usually offer groundbreaking ceremonies which offer positive media attention,” politicians were generally not motivated to support ITS projects.¹⁵²

This challenge continues today. Both state highway administrators’ preference for traditional highway investments and lack of funding for ITS projects were

apparent in the distribution of stimulus money as part of the American Recovery and Reinvestment Act (ARRA). Many states have not invested any ARRA funds in ITS.¹⁵³ As Kevin Lacy, State Traffic Engineer for North Carolina DOT explained the view of some state DOTs toward ITS, “The ITS industry is not as developed, still growing and often perceived as a little higher risk. So having strict time periods on cashing out has likely reduced opportunities for ITS projects using ARRA.”¹⁵⁴ Unfortunately, this perspective misses that there are many readily-available ITS technologies that can be deployed, that they offer superior benefit-cost returns, and also that ITS deployment can likewise stimulate economic and employment growth.

In summary, the United States has every bit the technological capability that Japan, South Korea, Singapore, and other countries possess in ITS, and actually had an early lead in ITS technology in the 1990s with the advent of global positioning system technology and first-generation telematics systems. (In fact, many ITS technologies have been initially developed in the United States but found much greater adoption and deployment elsewhere.) But institutional, organizational, policy, and political hurdles have allowed other countries to wrest the vanguard of leadership from the United States at making the benefits of intelligent transportation systems a reality for their citizens. This report now turns to examining the factors explaining that dynamic.

WHY COUNTRIES ARE LEADERS AND WHY THE UNITED STATES IS BEHIND

Both policy and non-policy factors explain country leadership in intelligent transportation systems. This section assesses the non-policy and then the policy factors explaining country leadership in ITS.

Non-Transportation Policy Factors

Geography and Economic Growth

In Japan, South Korea, and Singapore, increased transportation demand coupled with a limited ability to expand physical supply has driven these countries to adopt intelligent transportation solutions. These countries’ highly constrained geographies, including the lack of land and steep terrain, severely constrict the construction of new roadway capacity and forced politicians and policymakers alike to recognize at an early stage that they had no choice but to maximize the

efficiency of their installed highway capacity.¹⁵⁵ Japan's transportation agencies also face highly concentrated and restrictive land use policies, furthering the impetus towards ITS.¹⁵⁶

South Korea faced a related dynamic, when its explosive economic growth from the 1990s to mid-2000s led to dramatic growth in automobile ownership and traffic that overwhelmed the country's ability to build new highway capacity, leaving it little alternative but to turn to intelligent transportation systems to extract the maximum capacity out of its existing roadways (and the new ones it was feverishly building).¹⁵⁷

Population Density

These countries also benefit from higher population density, so that investments in intelligent transportation systems in concentrated areas are able to benefit a considerable percentage of their citizens. For example, 40 percent of the Japanese population lives in the vicinity of Tokyo, and a similar percentage of South Koreans live in the vicinity of Seoul. Singapore has an even higher population density. Deployed ITS systems in these countries thus benefit a greater number of drivers per mile of roadway.

While geography and population density do have some value in explaining country leadership in ITS, they are not the most important factors. For example, there are many locations in the United States that suffer serious geography-imposed capacity constraints, including much of the West Coast, especially California, and cities in the Northeast, where it is very difficult to build new roads (as evidenced by the fact that the United States has not built much new roadway capacity in the past 20 years), but the United States has still under-invested in ITS. Likewise, with regard to population density, many locations in the United States are quite dense (and the United States has a greater number of motorists) so amortizing the costs of ITS system deployments should be lower than in other countries, but this fact has not contributed to spurring ITS investment in the United States.

Cultural Factors

Cultural factors contribute to explaining international country leadership in ITS to a certain degree. A unique reason why Japanese consumers were among the earliest adopters of satellite-based navigation systems pertains to the country's residential address numbering

system. Unlike in the United States, where residential addresses follow a sequential numbering system by street, the Japanese system numbers houses by the year in which they were built, making finding a particular house on a street a real challenge. Satellite-based in-vehicle navigation systems thus addressed a particular painpoint for Japanese motorists, finding an early, enthusiastic marketplace.

In Japan, South Korea, and Singapore, increased transportation demand coupled with a limited ability to expand physical supply has driven these countries to adopt intelligent transportation systems.

Another contributing non-policy factor for Japan's ITS leadership has been a general disposition among Japanese consumers towards being (often price neutral) first adopters of new technologies and devices.¹⁵⁸ As *Wired Magazine* notes, "Neat-looking gadgets are a core aspect of one's identity in Japan."¹⁵⁹ The same holds true for South Koreans.

According to Dr. Keung-Whan Young of ITS Korea, a cultural factor contributing to the demand for intelligent transportation systems in South Korea has been that "The Korean people want to get information anytime, anywhere, at any place; it's part of their ethnic heritage that people will want to know information about their family and relatives and their safety and whereabouts. For example, Korean parents will give their kids mobile phones as early as age five to be able to communicate in real-time in case there is an accident."¹⁶⁰ Dr. Young argues that this cultural insistence for access to real-time information in South Korea has translated into popular demand and support for advanced public transportation systems in South Korea, noting that, "public transit users want to know, 'Where is my bus?'; 'When is it coming?'; 'Why is it late?'" Dr. Young argues that the demand for real-time information and awareness in South Korea contributed to popular backing of funding for APTS solutions such as Seoul's Bus Information System (not to mention consumer adoption of real-time traffic information services).

One final cultural factor deserving mention is that citizens in most Asian countries have been less deterred

by privacy concerns than U.S. citizens. It is perhaps a cultural strength that these countries are better at putting their heads down and forging ahead, being less concerned with theoretical harms that might occur than with the specific benefits they can realize from deploying intelligent transportation systems or other advanced technologies.¹⁶¹ In contrast, in the United States there has been active opposition to red light cameras, to satellite-based vehicle-miles traveled systems, and even to electronic toll collection because of privacy concerns. These types of privacy concerns do not appear to be raised as extensively in countries leading the world in ITS.

Policy Factors

Policy factors appear to be much more important than non-policy factors in explaining international leadership in ITS. Overall, the lesson from analyzing policy factors in the countries leading ITS deployment are: Countries must have a comprehensive national vision for the promise and impact of intelligent transportation systems, countries must sufficiently fund capital investments in ITS, and they must pursue a coordinated, focused national-level ITS implementation.

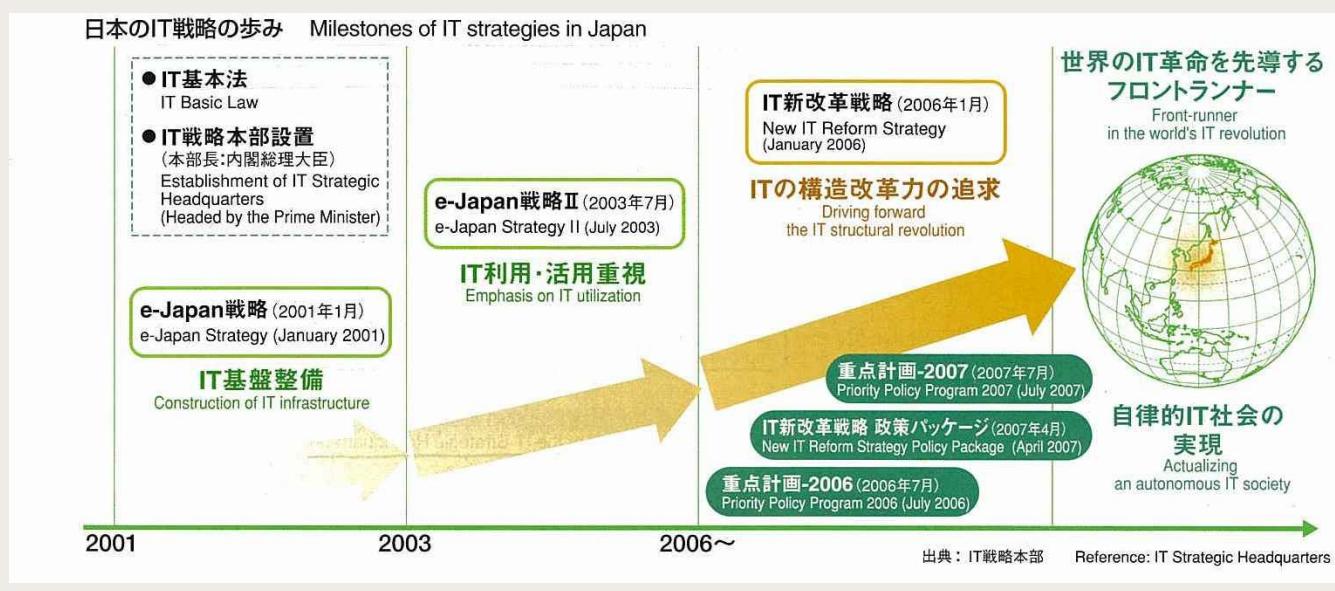
Governments' Explicit Recognition of the Importance of and Vision for ITS

One reason why Japan, South Korea, and Singapore lead in ITS is because these countries view ITS as one of a suite of IT applications or infrastructures that will

transform their societies and drive economic growth. As such, they have focused on establishing policies for digital transformation generally, and ITS transformation specifically, and have made both a national priority. As ABI Research noted, “Japan and South Korea lead the world in intelligent transportation systems, and national government agendas are among the most significant drivers for the development of ITS there.”¹⁶² In contrast, there has been no national vision for IT transformation in the United States and as such, ITS, to the extent it gets attention and funding, is seen as simply an adjunct tool that might make transportation a bit better.

Japan's seminal 2001 eJapan Strategy set a “national strategy which aimed to transform Japan into one of the most advanced nations in information technology within five years,” and explicitly “recognized a pillar of this strategy to be establishing public transport systems which rely on advanced information communications technologies.” In 2006, the New IT Reform Strategy updated the 2001 eJapan vision, aiming “to complete the IT reformation by 2010 before other countries and to create a society in which all people feel the benefits of IT.” The New IT Reform Strategy specifically established “Guidelines for the Informatization of the Road,” aiming “to make roads in Japan the safest in the world.” Figure 12 illustrates the evolution of Japan's information technology competitiveness strategy; ITS has been a core component of each milestone.

Figure 12: Evolution of Milestone IT Strategies in Japan¹⁶³



In June 2007, the Japanese Cabinet announced a long-term strategic vision for the country, “Innovation 25,” which articulated short- and medium-term policies on research and development, changes to social systems, training, etc. to create a more convenient, vibrant future for Japanese citizens by 2025. Innovation 25 set a goal that:

By 2025, intelligent transportation systems (ITS) will have been constructed that integrate vehicles, pedestrians, roads, and communities; and that have made traffic smoother, eliminated traffic congestion, and almost entirely eliminated all traffic accident fatalities. Smoother traffic will mean lower CO₂ emissions and logistics costs.¹⁶⁴

One particular aspirational vision Japan has set for ITS and its transportation system is to reduce traffic fatalities below 5,000 by 2012 and to eliminate them altogether by 2025. These policies crystallize how one of the primary reasons for Japan’s international leadership in intelligent transportation systems has been its government’s explicit recognition of the importance of ITS.

South Korea’s government has also acknowledged the power of information technology to drive economic growth and improve quality of life for its citizens, recognizing explicitly the impact IT can have in improving the country’s transportation system. In 2004, South Korea announced its IT 839 Information Technology Development strategy, which identified eight key services areas, three telecommunications infrastructures (ubiquitous next-generation broadband networks, ubiquitous sensor networks, and implementation of the IPv6 next generation Internet protocol), and nine information technology product areas that South Korea seeks world leadership in. The IT 8.3.9 strategy identified ITS as one of the eight key service areas.¹⁶⁵ Of course, beyond its strategic national IT plan, South Korea also created and implemented a specific ITS Master Plan.

Likewise, Singapore has both a national IT strategy and an ITS Master Plan. Intelligent Nation 2015 (iN2015) is Singapore’s 10-year IT master plan (through 2015), led by the Infocomm Development Authority of Singapore (IDA), designed to help the country maximize the potential of IT. iN2015 follows on the country’s previous information technology master plans, includ-

ing InfoComm 21 (2000 to 2003) and Connected Singapore (2003 to 2006).¹⁶⁶ Singapore’s decision to create the Land Transport Authority to control policy and administration for all modes of transportation was based on the desire to bring together all aspects of land transportation in order to holistically plan for its development, given the scarcity of land in Singapore.¹⁶⁷ The ITS community in Singapore attributes much of the country’s success with ITS to sustained government leadership. As one observer commented, “Many of the ITS initiatives in Singapore, especially congestion charging, required a government that had strong political will as well as foresight.”¹⁶⁸

The lessons from analyzing policy factors in the leading ITS countries are clear: countries must have a comprehensive national vision for the promise and impact of ITS, must sufficiently fund capital investments in ITS, and pursue a coordinated, focused national-level ITS implementation.

While Japan, South Korea, and Singapore are leaders in ITS because they have possessed a commitment to overall IT leadership for some time, Europe is making a concerted effort to catch up. In 2006, the European Union launched its i2010 initiative (successor to the EU’s e-Europe initiative) to create a unified European information space. i2010 was explicitly placed in the context of the European Union’s re-launched Lisbon Strategy, whose optimistic objective is to make the European Union, by the end of 2010, “the most dynamic and competitive knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs, greater social cohesion, and respect for the environment.” Likewise, i2010 emphasizes the significant contribution of information communication technologies to growth and employment and identifies intelligent transportation systems as one of the core information communication technologies. As Edgar Thielman, Head of Unit for the European Union Transportation Directorate, explained, “The European policy approach links technical, economic, and social progress, and intelligent transportation systems sit at the intersection of these three goals.”¹⁶⁹ However, compared to Japan, South Korea, and Singapore, Europe’s ICT focus was slightly later in coming and as a result, while the policy vision is there, implementation is still being worked out.

In contrast to Japan, South Korea, and the European Union, the United States does not have a national information technology strategy and has not proclaimed a goal of international IT leadership. While the United States is now in the process of developing a national broadband strategy, which may well be forward-thinking about several technology applications such as near field communications-based mobile payments or health IT, it is unlikely to include intelligent transportation systems, at least in any significant way. Overall, the United States really has not undertaken an extensive assessment of how information technology can transform the country's society and economy, and to the extent it has done so, it is late to the game. In contrast to these other countries that recognize the key role of government in assisting their countries through an IT-enabled transition, the United States has largely believed, incorrectly, that this is something the private sector can do on its own. To the extent that the United States has developed an ITS plan, it is not connected to a national IT strategy, is relatively late in coming and cautious in its goals, and is not yet a plan with clearly articulated goals for national deployment of ITS.

Degree of Centralization in ITS Decision-Making Authority

The degree of centralization in ITS decision-making authority may be the most important policy factor for ITS success. The importance of centralized ITS decision-making is pertinent from two perspectives: The extent to which transportation—and hence intelligent transportation systems—policymaking and implementation authority resides at a national level or at the state/regional level, and the extent to which ITS decision-making authority resides with a single (or final) agency or authority.

The degree of centralization is one of the most important explanatory factors because, as discussed previously, many intelligent transportation systems have chicken-or-egg characteristics, face very difficult system coordination problems, and often require scale and need to be implemented at a nationwide level. Local or state actors may not have the same willingness to innovate or invest in ITS, and even if they do they are unlikely to have sufficient funding or the ability to reach sufficient economies of scale. For all these reasons, national level vision, leadership, and coordination are essential for ITS success.

The countries leading the world in developing and deploying intelligent transportation systems feature strong government leadership in crafting a clearly-articulated ITS vision, setting a national agenda, convening relevant stakeholders, and spearheading implementation. Japan, Singapore, and South Korea have the advantage of being unitary polities that permit strong policy setting and coordination at the national level.

ITS is the 21st century, digital equivalent of the Interstate Highway System and needs the same level of federal government leadership that the development of the Interstate Highway System enjoyed.

For example, in Japan, transportation policy is set at a national level by the Ministry of Land, Infrastructure, Transport and Tourism, supported by the National Police Agency and the Ministry of Internal Affairs and Communication.¹⁷⁰ In Singapore, all modes of transportation administration, and ITS policy, are under the control of a single agency, the Land Transport Authority.¹⁷¹ This allowed Singapore to integrate and synchronize its application of ITS technologies across roadways and public transportation, including buses and rail, right from the beginning. South Korea charged the Ministry of Construction and Transportation with spearheading the country's ITS deployment.

This contrasts with the United States' federal system, where transportation policymaking is distributed, being devised and implemented at national, state, and regional levels. As the Director of one U.S. state's Department of Transportation remarked, "There has not been much national level policy guidance for ITS in the United States."¹⁷² Whereas it has been a challenge for the United States, the centralized nature of transportation policymaking in Japan, South Korea, and Singapore has enabled these countries to articulate clear and concise national ambitions and objectives towards ITS.

Closely related to the centralization of ITS authority is the issue of which entity or level of government actually "owns" or has control/authority over the roadways. In Japan, MLIT, along with the National Police Agency, has control over the roadways. For Japan, national

LESSONS FOR NATIONS THAT SEEK TO BE ITS LEADERS: TEN POLICY PRINCIPLES

This section lays out ten policy principles for ITS that transportation policymakers the world over should follow, and identifies where the United States, in the aggregate, stands vis-à-vis world leaders in exemplifying these principles.

- 1. Recognize intelligent transportation systems as a “force multiplier” for the transportation network.** ITS enable countries to extract maximum capacity from their existing transportation system. While implementing intelligent transportation systems may not be as visible as breaking ground for a new Interstate, money invested on ITS consistently outperforms other projects and delivers more benefit per dollar spent. (United States: Trails world leaders.)
- 2. ITS enable countries to shift to performance-based transportation systems by facilitating better collection of data to measure performance.** Many countries have recognized the need to move from a politically based system of allocating transportation investments to one that uses performance-based cost benefit analysis as the basis for transportation investment decisions. ITS helps decision makers accumulate the quality data needed to make sound performance-based investment decisions. (United States: Trails world leaders.)
- 3. Governments have an important role to play in convening and co-developing platforms that enable industry, academic, association, and government entities at the federal, state, and local levels to collaborate on the development of intelligent transportation systems and technology.** Ultimately, the most effective countries at deploying intelligent transportation systems have been able to successfully forge public-private partnerships within their polity. (United States: Slightly trails world leaders but is attempting to catch up.)
- 4. Governments need to articulate an ITS vision for their country (state, or community).** But it must be one fully informed with the input of key stakeholders in the ITS system. The importance of a clearly articulated ITS vision is a recurring theme in the ITS literature. (United States: Lags world leaders but is attempting to catch up.)
- 5. Governments must provide funding for both ITS R&D and deployment.** This funding should support ITS technology development test beds and proof of concept demonstrations, and then extend to ITS deployment. (United States: Strong at setting up test beds and technology demonstrations. Lagging at transitioning from ITS R&D to ITS deployment.)
- 6. The most successful countries view their ITS investments as creating a platform through which the private sector can develop value-added products and services.** They also preserve a strong role for competition, especially in awarding ITS application research and development grants or contracts to the private sector. (United States: Appears to slightly trail world leaders.)
- 7. Governments have a critical role to play in spearheading the co-development of interoperable standards for intelligent transportation systems and platforms.** In a dynamic marketplace, vehicles need to have standards that interoperate in any jurisdiction. This role extends both domestically and internationally, including, for example, setting common standards for electronic toll collection within a country, but also including working with the international community to establish common standards to enable vehicles to communicate with one another when they cross borders. (United States: On par with world leaders.)
- 8. Leading countries have fostered close alignment between transportation and telecommunications regulatory agencies and technology communities in their countries, recognizing the critical importance of allocating wireless spectrum or radio frequencies for intelligent transportation systems.** ITS is inextricably linked to the wireless transmission of information from vehicle-to-vehicle or from vehicle-to-infrastructure. Wired broadband networks are also critical to connect transportation management centers both to one another and to field-deployed assets in the transportation system, such as dynamic messaging signs or other roadside equipment. (United States: On par with world leaders.)
- 9. Governments should fund deployment of infrastructure to collect real time-traffic information.** Transportation agencies should make this information, at least in basic form, available to the public through the Internet. Governments' roles in collecting and disseminating traffic information should be similar to their role in collecting and disseminating weather information.¹⁷⁹ This information can then be used by the private sector and others to provide value-added services. (United States: Trails world leaders.)
- 10. Develop a national ITS technical architecture that can serve as the template for the implementation of ITS at federal, state or provincial, and regional, community, or local levels.** This has been a strength of the United States, Japan, and South Korea.

ownership of the highways has meant the government could move forward directly with deploying intelligent transportation systems. On most roadways in continental Europe, national ownership is the norm as well. A quite different situation prevails in the United States, where states or localities have authority over the vast majority of roads, and the only roads in the United States under the direct control of the federal government are those that traverse national parks or military installations.¹⁷³ Likewise, the U.S. government funds only 20 percent of annual expenditures on highways in the United States, with states and local municipalities providing the vast majority.¹⁷⁴ Moreover, the deployment—and ongoing operation—of most intelligent transportation systems in the United States is the decision and responsibility of states and localities.

As a percentage of GDP, South Korea and Japan each invest more than twice as much in intelligent transportation systems than the United States.

So entrenched is the view that states and localities implement surface transportation policy in the United States that it is somewhat anathema to many to suggest that the federal government take a more active role in ITS implementation. But it is not as if the United States is incapable of exercising federal leadership over the national transportation system. The Interstate Highways Act, and the building of the Interstate Highway System, was largely a federal initiative. The federal government funded it, set the design standards (down to the width of Interstate highway lanes), and even selected the routes. Certainly the states were partners in building the Interstate, but the United States would never have had an Interstate Highway System if the federal government had simply given money to the states and suggested they build it. ITS is the 21st century, digital equivalent of the Interstate Highway System, and needs the same level of federal government leadership that the development of the Interstate Highway System enjoyed.

In summary, the U.S. Department of Transportation needs to move from a focus on research to leadership. DOT needs to set a vision for ITS, including defining what the states need to do, ensuring that the states are deploying open, interoperable technology, funding

most of the deployment of nationally integrated ITS systems, and holding states accountable for results. One of the main reasons for this is that the portion of ITS that have system interdependencies requires a national approach. Another reason for the need for national leadership is that while all state DOTs have deep expertise in conventional transportation technology (for example, pavement and bridges), many may lack either expertise or interest in ITS. Centralizing that knowledge in one location makes more sense.

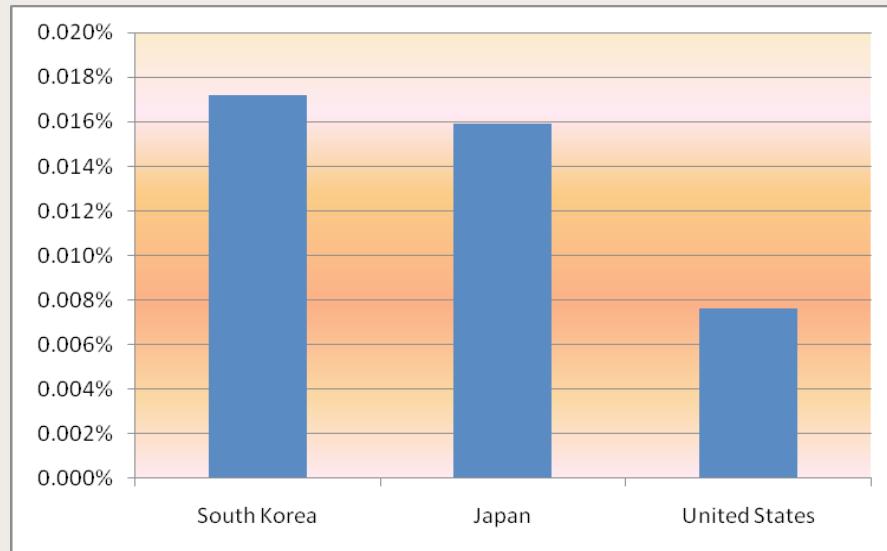
Government Funding for Intelligent Transportation Systems Development

The leading countries in intelligent transportation systems have not only developed an explicit national strategy for ITS, they have also invested heavily in it. South Korea's National ITS Master Plan 21 commits to investing a total of \$3.2 billion from 2007 to 2020 in intelligent transportation systems, an average of \$230 million annually over the fourteen-year period. Japan invested ¥64 billion in ITS from April, 2007 to March, 2008 and ¥63.1 billion in ITS from April, 2008 to March, 2009, on average about \$690 million annually.¹⁷⁵ Aggregate investment in ITS at all government levels in the United States in 2006 was approximately \$1 billion (including \$110 million in federal funding and over \$850 million in funding from the U.S. states).¹⁷⁶ As a percentage of GDP, South Korea and Japan each invest more than twice as much in intelligent transportation systems than the United States (Figure 13).¹⁷⁷

Viewing ITS as a Multi-Purpose Platform and Partnering with the Private Sector

An important lesson from the success of Japan's VICS and Smartway travel information systems is the need to view intelligent transportation systems platforms as "multi-use infrastructure." VICS and Smartway were designed and built using a strategic roadmap that envisioned multiple use cases for the intelligent transportation systems infrastructure, including of course safety applications and the public provision of real-time traffic information, but also viewing the infrastructure as a platform for the private sector to introduce value-added ITS applications. For example, while the "VICS Consultative Liaison Council" was convened in March 1990 by the National Police Agency, Ministry of Internal Affairs and Communications, and Ministry of Land, Infrastructure, Tourism and Transport, within eighteen months industry and academia were enrolled

Figure 13: Investment in ITS as a Share of GDP Amongst Selected Countries¹⁷⁸



in the development process through the “VICS Promotion Council,” formed in September 1991. The essential point is that in designing the VICS system, Japan’s government partnered with its private sector to understand how commercially viable business models for value-added ITS services could be built off the VICS platform.

The ability to forge successful public-private partnerships (PPPs) has been a key differentiator for Japan and South Korea’s leadership in intelligent transportation systems. The United States has found it more difficult to forge public-private partnerships in intelligent transportation systems, for many reasons, including legal, institutional, political, and leadership hurdles. Insufficient guidelines exist to guide development of public-private partnerships of ITS in the United States, and several of the failed experiences to date risk tarnishing perspectives towards PPPs. The contrast between Japan’s and South Korea’s, as compared to the United States’, efforts to forge public-private partnerships in the collection and dissemination of real-time traffic information, as documented earlier, could not be more stark.

Whatever the reason, it appears clear that leading countries, including Japan, South Korea, and Singapore, have demonstrated superior ability than the United States to forge ITS-related public-private partnerships. Testaments to this include VICS and Smartway in Japan and South Korea’s close cooperation with the Korea Expressway Corporation on the implementation of

intelligent transportation systems and the provision of real-time traffic information. In Singapore, the Land Transport Authority partnered with privately-owned taxis to turn them into probe vehicles. Part of the national leadership vision for ITS in the United States should be to not only lead the states and regions, but also the private sector, in the development of intelligent transportation systems.

POLICY RECOMMENDATIONS

Over the next five years, the United States is poised to hopefully invest more than \$500 billion on the nation’s surface transportation infrastructure.¹⁸⁰ Intelligent transportation systems must be a critical component of these investments in order to maximize the operational performance of the transportation system and attain the benefits enumerated in this report. If the United States is to achieve even a minimal ITS system, the federal government will need to assume a far greater leadership role in not just ITS R&D, but ITS deployment. In short, it is time for the U.S. Department of Transportation to view ITS as the 21st century, digital equivalent of the Interstate highway system, where, like then, the federal government took the lead in setting a vision, developing standards, laying out routes, and funding its construction.

Since the Interstate system was for the most part completed, the surface transportation policy community has collectively struggled with defining the appropriate role of the federal government in our nation’s surface trans-

portation system. While this report does not presume to comprehensively identify that role, it does suggest that in the 21st century digital economy one key role is for the federal government to take responsibility for the development and implementation of a world-class ITS system across the United States. Just as building the interstate highway system did not mean an abandonment of the role of states, neither does this new role. But just as the building of the Interstate required strong and sustained federal leadership, so too does transforming our nation's surface transportation through ITS. Specific policy recommendations include:

- Significantly increase funding for ITS at the federal level, by \$2.5 to \$3 billion annually, including funding for large-scale demonstration projects, deployment, and the ongoing operations and maintenance of already-deployed ITS systems. Specifically:
 1. **The next surface transportation authorization bill should include \$1.5 to \$2 billion annually in funding for the deployment of large-scale ITS demonstration projects.**

ITS will not reach critical mass unless the United States begins to fund large-scale research, demonstration, test and evaluation (RDT&E) projects, as opposed to small “one-off” projects that currently, collectively, do not comprise a system. Moreover, rather than funding almost all ITS deployments through individual states, it would be better for the United States to also fund larger-scale consortia from the federal level. This would address the problem that ITS deployments in the United States tend to be sporadic, incremental one-off deployments scattered locally around the country and move the United States towards funding demonstration and deployment of large-scale, nationally integrated ITS systems.

To achieve this, the U.S. Department of Transportation should expand the remit of RITA's ITS Joint Program Office beyond research and development to include deployment. The JPO should be charged with developing, implementing, and managing a number of large scale collaborative RDT&E projects focused on substantive and functional areas related to ITS, including:

1. Development of a nationwide real-time traveler information system;

2. Developing large scale platforms to conduct real-time analysis of traffic-related data from millions of vehicles.
 3. Real-time transit information systems, including “peer-to-peer” transit systems;
 4. Development and deployment of smart traffic signal systems that respond to vehicles' presence;
 5. Improved incident response and traffic operations management systems;
 6. Testing to fully prove the viability of a user-miles traveled pricing system;
 7. Freight monitoring systems (for example, real time weigh stations);
 8. Model implementations of IntelliDrive in several large U.S. cities.
2. **The next surface transportation authorization bill should provide dedicated, performance-based funding of \$1 billion for states to implement existing ITS systems and to provide for ongoing operations, maintenance, and training for already-deployed ITS systems at the state and regional levels.**

Currently, ITS projects often have to compete with conventional transportation projects for funding, such that ITS projects, which are poised to deliver greater long term benefits, may have to compete with projects that, while they may be immediately pressing, are not positioned to deliver as great long-term benefits, such as road repair or even new road construction. In addition to a lack of funding (which tends to exacerbate focus on more immediate concerns at the expense of a longer-term vision of the benefits of deploying ITS applications), bureaucratic inertia or a lack of interest, technical skill, or knowledge of ITS benefits have made it more difficult for ITS projects to compete with conventional transportation projects out of the same funding pools.

- **Tie federal surface transportation funding to states' actual improvements in transportation system performance.**

The Department of Transportation needs to allocate surface transportation funding to states much more on the basis of performance. Currently, the funding allocations for the major

programs (for example, National Highway System, Interstate Maintenance Program, and Surface Transportation Program) are based largely on formulas reflecting factors such as state lane miles and amount of vehicle miles traveled. As a result, while there is substantial process-based accountability for how federal funds are used, there is woefully little attention paid to results. Performance measurement, evaluation, and benchmarking are notably absent from surface transportation funding. Transportation agencies at all levels of government face virtually no accountability for results. To address this, a modest share of highway trust funds should be allocated to states based on relative progress in three facets: congestion relief predominantly, but also vehicle emissions and safety.¹⁸¹

Holding states accountable for real results will allow federal and state transportation funds to go farther, achieving better results for the same amount of funding. It will also provide stronger incentives for states to adopt innovative approaches to managing highways, including implementing intelligent transportation systems. One reason ITS has not been as widely deployed in the United States is because state DOTs continue to be largely focused on their traditional roles of overseeing the building and maintenance of bricks and mortar infrastructure. Given that ITS can in many cases have better performance on mobility, safety and emissions than building conventional infrastructure, holding states accountable for performance will have the effect of putting ITS on a level playing field with concrete, steel, and asphalt. It would also send a clear message to the states that the federal government values ITS and expects to see its implementation. Moreover, there is a positive synergy between greater performance standards and ITS. Performance standards will drive ITS, while ITS will enable performance to be better measured.

In order to move to a more performance-oriented transportation financing system:

- Congress should charge DOT with developing an ITS assessment and benchmarking study that would: 1) make a rigorous assessment of the cost-benefit

impacts of ITS projects that have been deployed in the United States over the past two decades, and 2) develop benchmarks for state adoption of ITS. Each year, DOT should issue a status report, holding states accountable to these ITS adoption benchmarks. As part of developing these benchmarks, DOT should develop performance goals for traffic-related fatalities, traffic congestion, and travel times.

- Congress should require each state DOT and MPO (metropolitan planning organization) to develop a performance management process to monitor progress toward meeting national performance goals. State DOTs and MPOs should establish short-term and long-range performance targets in areas including traffic-related fatalities, traffic congestion, and travel times, and provide regular performance reports on their progress towards meeting established performance targets.
- DOT should make funding available to state DOTs, MPOs, or local agencies that lack the ability to collect necessary performance data in order to fill the gaps in their data collection systems (including through the use of ITS systems).
- Data on traffic-related fatalities, congestion levels, travel times, and other performance measures should be published by DOT at least once annually as part of a National Scorecard. This data should be made publicly available in an exportable, electronic, Web-based format.
- **Congress should charge DOT with developing, by 2014, a national real-time traffic (traveler) information system, particularly in the top 100 metropolitan areas, and this vision should include the significant use of probe vehicles.** By 2014, the top 100 metropolitan areas should have at least 80 percent of freeway and arterial miles enabled by real-time traffic information systems (including incident notification, travel time, and travel speed data), and that information should be available in an interoperable format so that it can be used on any kind of Web, mobile, or in-vehicle application. States should make real-time traffic

information freely available to the general public, akin to how the National Weather Service makes weather data available.

In leveraging probe vehicles to collect real-time traffic information, the system should employ government vehicles, taxis, and even private fleets that would want to participate. For example, corporate vehicle fleets include hundreds of thousands of vehicles. If necessary, voluntary vehicles could receive a modest subsidy (such as a slightly reduced vehicle registration fee) for installing the probe device. States with cities in the top 100 metropolitan areas that do not achieve real-time traffic information collection and dissemination on 80 percent of their freeway and arterial roadways by 2014 should be penalized each year with fewer federal transportation dollars.

- In the next surface transportation authorization bill, Congress should authorize a comprehensive R&D agenda that includes investments in basic research, technology development, and pilot programs to begin moving the United States to a mileage-based user fee system (VMT system) by 2020. The research should be overseen by a multi-modal body within U.S. DOT that combines technology, policy, tax administration, and systems expertise. As recommended by the National Surface Transportation Infrastructure Financing Commission, the first set of studies should be wide-ranging and experimental, testing various self-selected VMT fee processes. Subsequent tests would be more prescriptive to facilitate the selection of a single, nationally interoperable system.¹⁸²

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ABOUT THE AUTHOR

Stephen J. Ezell is a Senior Analyst with the Information Technology and Innovation Foundation (ITIF), with a focus on international information technology competitiveness and national innovation policies. Mr. Ezell comes to ITIF from Peer Insight, an innovation research and consulting firm he co-founded in 2003 to study the practice of innovation in service industries.

Prior to co-founding Peer Insight, Mr. Ezell worked in the New Service Development group at the NASDAQ Stock Market, where he spearheaded the creation of the NASDAQ Market Intelligence Desk and the NASDAQ Corporate Services Network, each a service to NASDAQ-listed corporations. Stephen holds a B.S. from the School of Foreign Service at Georgetown University, with an Honors Certificate from Georgetown's Landegger International Business Diplomacy program.

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