USING TECHNOLOGY TO MANAGE AND OPERATE 21ST CENTURY TRANSPORTATION SYSTEMS

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TABLE OF CONTENTS

Executive Summary

This paper examines the role that technology might play in helping transportation agencies to better manage the nation's highway and transit network. The focus is on improvements to management, but the implications go well beyond what one conceives as day-to-day operations. The quality and quantity of information that technology can provide also offers opportunities for transport agencies to improve how they support overall economic growth and opens the door to financial techniques that may also encourage economic productivity. The ability to fund and deploy these systems depends in part on the private sector, so a brief mention is made of private and consumer benefits.

This report uses a limited definition of technology, with an emphasis on devices used to collect and communicate information about the highway and transit networks. This information may come from traditional sensors and related ITS equipment or it may come from information collected from within the vehicle. The use of vehicles as sources of information offers a powerful new source of data about the level of service experienced by travelers, about the roadway environment, and about accidents and how best to respond to them.

The ability to collect information from the vehicle also means it will be possible to provide drivers with the information they need to make more effective use of existing capacity (which mode to take, when to stay at home a bit longer, when you must leave for the airport, and so forth) and how to improve safety (avoid vehicles that may create a dangerous situation or adjust for risky road conditions). This report does not focus on what technologies transport agencies will need within the agency in order to take full advantage of these data.

Three significant opportunities derive from the ability to know where everything is and the condition of everything, whether vehicle or infrastructure.

1. **Apply more business-like management techniques**. These data will provide DOTs and transit agencies with the real-time information they need in order to manage their system using direct measures of the quality of service their customers receive. Most private business already operates with this advantage. This change has implications for operations, planning, design, and even how agencies interact with some of their customers (for example, see item three below).

2. **Implement performance-based pricing**. Real-time information on the quality of service on all significant roads and transit lines could open the door to large-scale use of performance based pricing. That is, travelers can be told the travel times they can expect – and how much they will pay to receive this level of service. This approach will encourage more effective use of our limited transportation capacity. It differs in concept from most congestion pricing schemes and differs in scale from HOT lanes (although very similar in concept).

3. **Improve link with economy.** Today's economy depends on reliability and predictability – also true of course for much of our non-work travel. Real-time information on the quality of service on all roads can be a powerful economic tool for a world that behaves as if everything were part of a supply chain. Transportation agencies can now develop a different business model, one that involves an active partnership with private industry, rather than making physical improvements and then hoping that industry responds positively. By integrating travel information, predicted travel times, and a performance-based system of rewards, highway and transit services could be coordinated to match the demands of today's businesses, with business being encouraged to shift how they use the network as one way to improve its efficiency. The result would be a transportation system based on "No Surprises."

Much work remains before such a comprehensive system of real-time information is available. A business case is needed to define specific benefits, quantify their value, assess willingness to pay, and identify institutional options. One goal of such a business case will be to identify a stream of funds to help deploy this new technology – and at a higher level than typical of recent years for ITS. In some cases (such as expanded ITS) the public sector has a lead role, in some (such as use of traffic probes) the private sector has a clear lead, while others (such as VII or the proposed system of vehicle-infrastructure integration) require a combination of public and private activity.

Background: Trends in Technology

The U.S. transportation network is the largest and most complex in the world. An efficient transportation system is essential for economic growth and to support an enjoyable and secure daily life. Nearly one in every nine dollars spent on goods and services in the United States economy is absorbed by transportation products and services.[1] Yet the efficiency of our transportation system remains at risk since congestion decreases reliability. In addition, an aging infrastructure needs constant attention and re-investment.

Day-to-day management of our surface transportation system – and thus the search for solutions – is largely in the hands of the fifty state DOTs, local transport agencies, and public transit authorities. Traditional solutions, including the addition of new lanes of highway and new bus and rail facilities, will continue to add tangible value. New physical capacity alone is not enough. Indeed, many public agencies already emphasize operations as part of their management approach. Technology can produce the information needed to take this new emphasis to a new level.

It is important to consider these opportunities within a broader framework.

Networks are key to economic and social progress. An important fact: the average economic rate of return to private business from investment in the nation's highway network exceeds the average rate of return from private sector investments as a whole.[2]

[1] US DOT, Bureau of Transportation Statistics.
[2] Delcan Inc. "Rate of Return from Highway Investment," Draft Report, (Fall 2003), NCHRP 20-24 (28).

This has been true for at least the last 50 years. Of course, there is no inherent reason why similar returns should not apply to other modes including airports and mass transit.

Returns are highest during periods that experience significant new capacity addition (for example, 50-60 percent a year while we built the Interstate System) and are highest for higher level roads such as the National Highway System. Unfortunately, public spending on technology (as with ITS) has been much slower than originally forecast, thus placing the full range of potential gains at risk. Further, since completion of the Interstate Highway System, the nation's transportation leaders have struggled to find the next national-scale network.

Economic and location patterns have changed dramatically from when we built the Interstate Highway System – indeed they have changed from just ten to twenty years ago. We now live in an age of supply chain economics, just-in-time delivery, global competition across almost every industry, continual change in the nature and organization of industry, complex urban patterns that are rarely oriented toward a single central business district and an economy dominated by services and high-tech manufacturing.

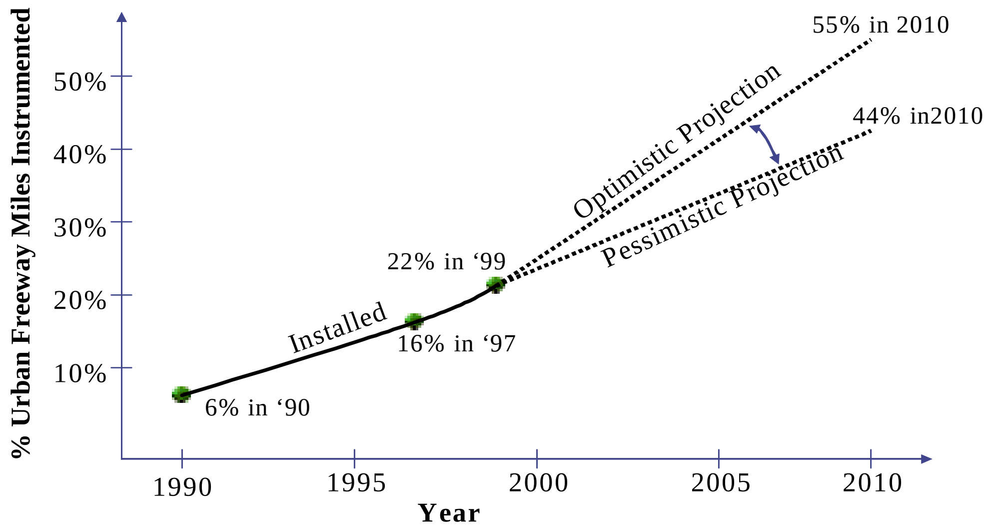
The peak-hour work trip may create much congestion, but it no longer dominants travel. Work force participation has increased significantly, placing greater pressures on how we use our transportation system. Reliability is important around the clock. Examples flow more easily from the business side of life, but these effects occur in almost every aspect of our daily lives.

Technology should be viewed as an important management tool and a way to provide higher quality services for less money. There is more here than ITS and a clever way to collect tolls. Technology makes it possible to implement basic economic principles in areas where action is not typically shaped by market forces.

Relative to most other industries, transportation has been slow to adopt technology (see Phil Tarnoff's famous "Progress is Glacial" chart that shows ITS deployment growing at 2-3 percent a year). One positive aspect of this fact is that a wide array of opportunities exists to "leapfrog" this trend – the equivalent of "going vertical" on the "Progress is Glacial" chart. Examples include:

- The ability to locate and track almost anything, whether by GPS or cellular tracking, with accuracy within meters (for GPS);
- Wireless communication that makes it possible to exchange data among vehicles and between vehicles and the highway; and
- An internet that allows low-cost, rapid communication worldwide.

Figure 1
Progress is Glacial



In recent years there has been a growing split in the pace of technology growth between the vehicle side (increasingly high tech) and the infrastructure side (business as usual). The number of sensors in each vehicle has grown rapidly, in part due to public demand for safety – and some believe that even more could be done as public agencies take a more active interest, perhaps including the purchase of traffic and operational data from private entities.[3]

A tangible sign of this change is interest in developing a VII network, or Vehicle-Infrastructure Integration (an extension of earlier concepts such as FHWA's proposed INFOstructure and ITS America's concept of the INTI). AASHTO, Automobile OEMs (original equipment manufacturers) and the US DOT have formed a working group to see how best to release the information available in many new cars so that the public sector might make full use of it – and of course so information could be recycled back to the automotive driver. Many details remain to be established, including the exact technical nature of the VII, who will build it, who will operate it, and of course, who will pay for it. Not surprisingly, the exact timing for when this new network will appear is uncertain, but the VII Working Group has mentioned estimates in the five to ten-year range.

A key part of the VII will be its reliance on a broadband wireless network to communicate among vehicles and between vehicles and the infrastructure. This effort to integrate wireless communication with the surface transportation system represents a break from past practice – and one in keeping with the needs of a 21st Century transportation system. Certainly transportation and tele-communications form a logical economic partnership since both provide ways to overcome distance.

[3] James R. Robinson, "The Future of Travel Time Data: A Paradigm Shift," Discussion Paper prepared for AASHTO Subcommittee on System Operations and Management, (Spring 2004).

Management and Operations
Most transportation agencies now think of their business as one that relies on operations as much (maybe even more) than it does on construction. We need new measures of performance that match today's (and maybe even tomorrow's) economic structure. Ton-miles and VMT were 19th Century measures of value. Speed was emphasized in many 20th Century investments, from highways to aviation.

Cost and speed have not been forgotten, but are less important in a world where reliability, predictability, and completed trips are what matter. This shift in value should have major implications for what we build and how we manage it. Technology can help make an effective measuring system possible, thus opening the door to a family of new management approaches. These changes, in turn, will require a new "corporate culture" within DOTs and other transport agencies.

Pure privatization has been an interesting side show but of limited value (except to some consultants). Our ability to apply **private-sector management principles** requires real-time, ubiquitous (beyond a few urban expressways) measures of performance that have a direct meaning for the traveling public. Speed and travel time information could fill this need, but only if they covered all roadways all the time.[4] If this were available, DOTs would have the opportunity to manage their systems with private-sector principles of accountability.

Defining the System

This report considers three primary frameworks: Intelligent Transportation Systems, the Vehicle Infrastructure Integration program and traffic probes. These approaches are under development along parallel tracks. Figure 2 provides a conceptual picture of the evolution for each category.

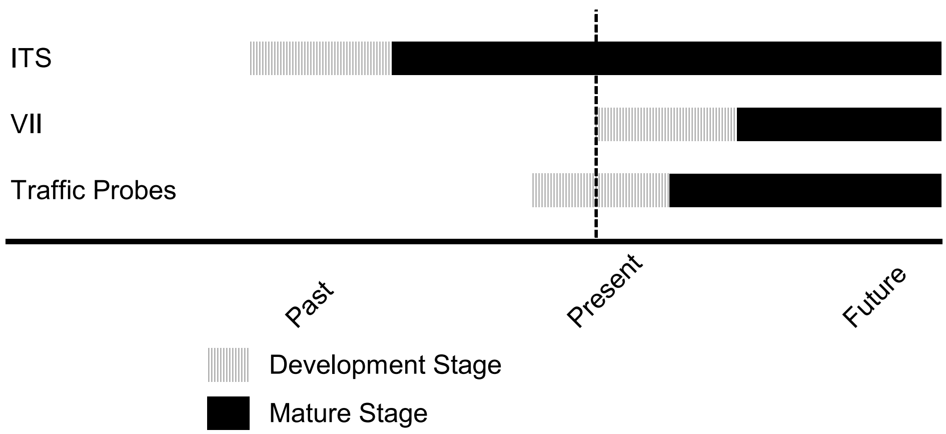
Intelligent Transportation Systems (ITS)

While ITS involves public-private partnerships, it is largely shaped by the public sector. ITS aims to use advanced technologies to help accomplish the public sector's mission of improved safety, increased system capacity, reduced travel times, and improved productivity. These efforts began to mature in the late 1980s and in 1991 Congress called for a "national system of travel support technology, smoothly coordinated among modes and jurisdictions to promote safe, expeditious, and economical movement of goods and people."[5] Adequate funding to meet this goal did not follow.

[4] These measures are only one step short of what might be the best measure of customer satisfaction – did you complete your trip on time? Safety is implied by phrase on time.

[5] Although deployment and development of ITS infrastructure rapidly accelerated in the 1980s, the seeds of ITS were planted decades earlier. For example, FHWA researched Electronic Route Guidance Systems in the 1960s and the first metered ramp was installed in Chicago in 1963. Even earlier, the General Motors pavilion at the 1939 New York World's Fair highlighted what we now call ITS and telematics.

Figure 2.
Development of Transportation Technology in the United States



ITS technologies encompass a broad range of hardware and software. FHWA has put a significant amount of funds into research, testing, standards development and deployment of these technologies. The private sector, however, typically provides the equipment under contract to DOTs and other public agencies. Table 1 shows examples of specific ITS technologies and their uses.

Although a large suite of ITS technologies exist, actual ITS deployment has been slower than expected. In 1996, Secretary of Transportation, Federico Pena stated, "I want 75 of our largest metropolitan areas with a complete ITS infrastructure in 10 years." By 2002, however, these 75

Table 1.
Commonly Deployed ITS Technologies

Technology	Use
Loop Detectors and other sensors	Monitor speeds and volumes on roadways
Variable Message Signs	Provide safety and traffic information to travelers
Traffic Signal Controllers	Adjusts traffic signal timing to reflect traffic flow
Closed Circuit Television Cameras	Traffic surveillance and incident detection
Radio Frequency Identification (RFID)	Collect tolls automatically

largest metropolitan areas had deployed only 26.8 percent of needed capital.[6] This leaves $33 billion to complete full deployment. This figure, however, assumes a very thorough

[6]Data on ITS costs from: Cheslow, Melvyn and Staples, Barbara, "Working Paper: National Costs of the Metropolitan ITS Infrastructure: Updated with 2002 Deployment Data." Mitretek Center for Telecommunications and Advanced Technology, October 2003.

system with redundancies and multiple technologies covering the same physical space.[7] As discussed below, the VII network and traffic probes offer a more cost-effective option for significant parts of this system. Even so, remaining costs are likely in the $10 to $20 billion range. This is not a small sum, but one that the nation could fund over the next five to ten years if it chose to do so.

Traffic Probes

Traffic probe systems use vehicles or cell phones to collect data on speed and travel times on most roads[8] and do this in real-time.[9] These vehicle-oriented systems are sometimes referred to as Floating Car Data. Typical methods to obtain floating car data include:

- Transponders such as those issued for Electronic Toll Collection – these collect travel time, but only between fixed points where readers have been installed.[10] While not "true" traffic probes since they rely on sensors, transponders differ in concept from traditional fixed sensors.
- GPS devices installed on commercial or public-sector vehicles – these then require some regular means of communication to download data.
- Cellular phones -- most proposed systems apply sophisticated statistical models to analyze data already collected by wireless firms.

One important aspect of floating car data is its relative low cost. The industry has proven many times that no market exists for poor quality traffic data, but FCD systems are capable of delivering real-time traffic data that are valuable to public and private entities alike. For example, ITIS Holdings has developed a national FCD network in the United Kingdom. Their customers include automobile manufacturers (Toyota, Ford, BMW, Nissan), telecoms (Vodaphone, T-Mobile, Orange), the British Automobile Association, and the UK Ministry of Transportation.

Several firms, including ITIS in the Baltimore Metropolitan Region, have regional tests underway in the U.S., although no wide-scale deployments have yet come to fruition.[11] AirSage has tested cell phones as traffic probes around Knoxville, TN and Norfolk, VA. Another firm, Zipdash, uses GPS enabled phones to collect data in San Francisco. As firms such as these refine their services and establish working business models, traffic probes will become more commonplace in the U.S. OnStar is rumored to have examined

[7] Some assumptions within the full build-out proposal include: all ramps metered, CCTV at every mile of freeway, loop detectors placed at half-mile spacing across all freeway lanes and every approach lane of a signalized intersection, and call boxes placed at half-mile intervals in each direction.
[8] The constraint on network coverage relates to the fraction of vehicles equipped as probes – less than five percent is considered adequate. The time required to collect these data depends in part on the type of communication used and the density of data needed to assure statistical significance for any speed or travel time reports.
[9] The phrase real-time is not equivalent to instantaneous, but rather refers to the ability to report traffic information in time for travelers and managers to make effective use of the information. This usually means delays measured in minutes.
[10] Systems to collect travel times using toll tags are in place or under construction in the New York Metropolitan area; the San Francisco Bay Area; San Antonio, Texas; and Houston, Texas.
[11] Commercial deployments exist in Tel Aviv, Israel and area underway in Scotland and Belgium.

floating car data possibilities based on their fleet of some three million GPS-equipped vehicles.

Vehicle Infrastructure Integration (VII)

VII is an informal working group that includes AASHTO, the Federal Highway Administration, and several automotive manufacturers. Its goal is to share real-time information between vehicle and infrastructure with a focus on safety implications. As of August 2004, however, few characteristics have been defined. These include timelines for the program's development and deployment, the appropriate broadband communications medium, overall business case, and a host of institutional issues and operating implications.

Nevertheless, the value of a nationwide Vehicle-Infrastructure system is understood on a conceptual basis. The applications and benefits from such a framework are far reaching. Table 2 provides a sample of the safety and consumer-oriented applications that such a system could facilitate. Some support commercial applications while others provide information to help state and local DOTs and public safety agencies to improve operations.

Table 2. Potential Applications of a System-wide VII Type Solution

Infrastructure-to-Vehicle	Vehicle-to-Infrastructure	Vehicle-to-Vehicle
Intersection Collision Warning	Post-Crash Warning	Vehicle-Based Road Condition Warning
In-Vehicle Signage	SOS Service	Post-Crash Warning
Road Condition Warning	Stop Sign Movement Assistance	Blind Merge Warning
Stop Sign Warning	Floating Vehicle Data	Adaptive Cruise Control
Adaptive Headlight Aiming	Intelligent On-Ramp Metering	Wrong-Way Driver Warning
Curve Speed Warning	Intelligent Traffic Lights	Blind Sport Warning
Dynamic Navigation	Electronic Toll Collection	Instant Messaging
Rail Collision Warning	Emergency Vehicle Signal Preemption	Vehicle-Based Road Feature Notification
Low Bridge Warning	Remote Diagnostics/Repair Warning	Visibility Enhancer
Work Zone Warning	Air Quality Warning	Lane Change Assistant

The success of the VII program will hinge upon having strong technical and financial support from both public and private sectors. This will require compromise and patience from both sectors since they have their own ways of working through issues and making decisions. Automobile OEMs (original equipment manufacturers) have begun to equip vehicles with sensors that offer potential value for transportation operations and traffic management (Table 3). Additional guidance from the public sector (perhaps reinforced with some hard cash), would give OEMs a clearer picture of the types of sensors and technological modifications they might consider including in their vehicles.

Table 3. AMI-C's Sensor Penetration Forecast for 2005 Vehicles

Sensor	Penetration	Sensor	Penetration
Air Bag	100%	Rear Window Defrost	50%
Vehicle Speed	100%	Exterior Temperature	25%
Hazard Signal	75%	Sun Sensor	20%
Headlights	75%	Antilock Brake System State	20%
Brake Applied Status	50%	Rain Sensor	20%
Cruise Control Set Speed	50%	Traction Control State	20%
Fog Lamps	50%	Vehicle Location	10%
Wiper Speed	50%	Obstacle Distance	10%

A major requirement for the VII is to build and operate a broadband wireless network that covers a significant portion of the nation's highway system. The cost to build the broadband wireless infrastructure portion of such a system is relatively modest, perhaps in the range of $2 billion to $3 billion. Automobile OEMs would provide the appropriate in-vehicle equipment and state and local transport agencies would fund the costs to analyze and use the new data. Presumably, automobile OEMs would deploy the sensors that would best fit within their business model although federal, state, and local agencies might appeal to automobile OEMs to install certain additional sensors in some cases. In such a situation, government subsidies to the producer or consumer could help speed this process and ensure services that meet specific needs.

The Rise of In-Vehicle Technologies

It was only 1982, but there was already a vehicle, produced by Knight Industries of San Lucus California, with auto collision avoidance, adaptive cruise control, vision enhancement, dynamic navigation and a variety of voice recognition/execution capabilities. Also handy, and often used, were the options of emergency ejection, auto pursuit and a myriad of surveillance technologies. There was only one problem, the single person certified to operate this technological marvel – powered by a turbojet engine (including modified afterburners) – was David Hasselhoff (a.k.a Michael Knight) once a week from 1982 to 1986 on the television program "Knight Rider."

During the five-year run of the "Knight Rider" television program, the term "telematics" was never used.[12] Even if the term was used, it would have meant something more in line with the generalized usage of computers and telecommunications[13] than anything automotive specific. Today, however, when one mentions telematics it is often assumed that they are referring to "automotive telematics," or the usage of computers and telecommunications devices in vehicles.

The telematics industry has grown impressively in recent years, but not always smoothly and not without a struggle. One of the earliest incarnations of telematics was the bulky car phone, which, while not pretty to look at, was the first widely used technology to connect car and driver to the outside world. It was not, however, until the mid-1990s when more robust telecommunications infrastructure, internet technology and advances in mobile computing devices made the potential of automotive telematics more apparent.

1996 was a groundbreaking year for telematics with General Motor's launch of the OnStar system, the first subscription-based telematics package. OnStar offered services such as stolen-vehicle tracking, automatic air bag deployment notification, remote horn, lights and door unlock and driving directions. It was not long before other firms entered the subscription telematics market to compete with GM's OnStar system, including Ford Motor Company's Wingcast, and aftermarket providers such as ATX Technologies.

The beginning of the 21st century brought with it the realization that expectations for the short and medium term telematics markets were too optimistic. These realizations closely mirrored an economy buoyed by inflated expectations from the technology sector. Capital for investment in the technology sector contracted, tech stocks dropped in value and some telematics providers left the industry (for example, Ford Motor Company's Wingcast in 2002).

Although not at the levels originally forecasted in the late 1990s, the telematics industry continued to experience steady growth from 2000 to 2003. Table 4 shows that the number of vehicle manufacturers and models lines offering telematics in North America increased from 2001 to 2003 while the average price of telematics components and telematics enabled vehicles fell. OnStar, for example, has continued to grow and in 2003 provided service to an estimated 2.5 million vehicle owners.

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[12] Scripts can be found here: http://members.fortunecity.com/knightriders/index2.htm .

[13] Telematics is the English version of the French word "*telematique*" originally coined by Simon Nora and Alain Minc in the book, "*L'informatisation de la Societe*" in 1980. Source: Dean Gillette "Combining Communications and Computing: Telematics Infrastructures" in the book, *Cities and Their Vital Systems: Infrastructure Past, Present, and Future* (1988) from the U.S. National Academy of Engineering.

Table 4. - North American Telematics Trends			
Year	**2001**	**2002**	**2003**
# of Vehicle Manufacturers offering Telematics	12	15	19
# of Model Lines offering Telematics	51	67	90
Average Vehicle Price	$40,166	$41,704	$38,496
Average Price of Telematics	$2,218	$1,900	$1,238
Sales of Telematics-enabled Autos	1,630,000	2,020,000	2,450,000

Source: *Automotive Telematics Gains Ground in North America; Telematics Research Group;* www.telematicsresearch.com

Looking forward, industry forecasts for telematics point to solid growth for the remainder of the decade, albeit at rates considerably smaller than those forecast in the late 1990s. One recent forecast by the Telematics Research Group (Figures 4 and 5) forecasts 12.9 million telematics enabled vehicles will be sold in the United States in 2010 (a 72.4 percent market share), up from approximately 2.4 million in 2003.

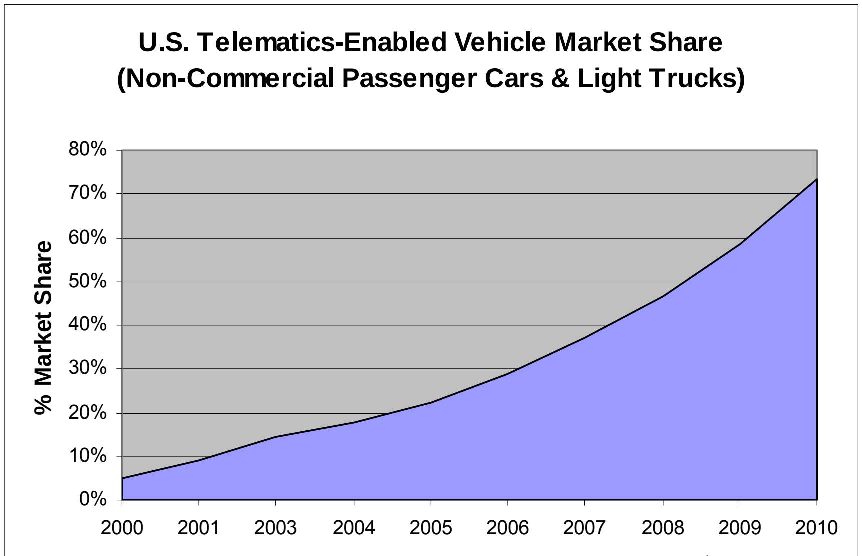


Figure 4

General forecasts of telematics, however, must be put into context. A diverse group of individual technologies make up the basket referred to as telematics: while some, such as vehicle location and roadside assistance, are typical components in existing subscription services, while others, such as driver fatigue monitoring/notification, are not yet offered commercially. Therefore, a general forecast of telematics enabled vehicles begs the question: but what specific technologies are included?

Table 6 illustrates some of the telematics technologies with implications for public sector transportation agencies. A few of these technologies are discussed following the table.

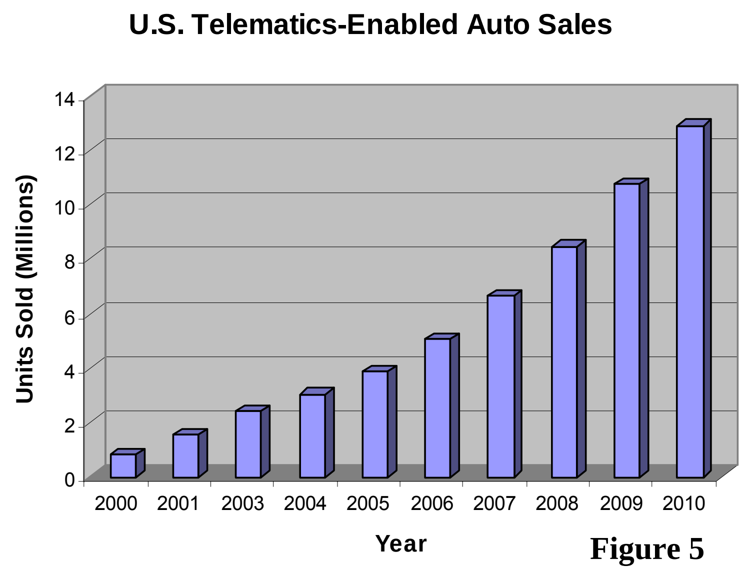


Figure 5

Table 6

Telematics Technologies Classified by State of Development		
	Safety and Security	**Information Services**
Technology Currently in Marketplace	●Roadside Assistance ●Vehicle Recovery/Tracking ●Remote horn/lights ●Door unlock/lock	●Navigation (using computerized static info) ●Transponders ●Navigation (using human attendant) ●Remote Human Concierge (assist driver with directions to ATMs, hotels, reservations, etc.)
Early Deployment	●Adaptive Cruise Control (Short Range Radar) ●Collision Notification ●Tire Pressure Monitoring System ●Vision Enhancement ●Lane Departure Systems (Vision Based)	●Discrete Weather, accident and event information
Testing Stage/Very Limited Deployment	●Driver Fatigue Monitoring/Notification ●Automated Intersection ●Throttle Controller ●Lane Mapping ●Adaptive Cruise Control (Long Range) ●Infrastructure-to-Vehicle Warnings (curve speed, signs, road condition, etc.) ●Vehicle-to-Vehicle Warnings (curve speed, signs, road condition, etc.)	●Dynamic Navigation (incorporates real-time traffic conditions) ●Black Box Data Recorder ●In-Vehicle Broadband Wireless Communications (Cellular, WiFi, DSRC) ●Remote Mechanic - Diagnostics

Safety and Security Technologies

- *Adaptive Cruise Control (ACC):* Adaptive cruise control uses radar and other sensors to maintain the distance, set by the driver, to the car in front. Although not yet widely deployed, these systems are being aggressively developed and tested. For example, General Motors has installed a full-blown collision-avoidance system in 10 Buick LeSabres, complete with radar, road sensors, global positioning, and adaptive cruise control. The cars began a year of testing in March of 2003 on Michigan roads. These prototypes, however, are still expensive with costs of about $100,000.[14]

- *Lane Departure Systems:* Designed to keep drivers from veering out of their lanes, the technology for these devices is primarily vision based, usually consisting of a camera which monitors a vehicle's location. These systems have primarily been deployed on commercial vehicles although they are finally beginning to migrate to the car. The systems currently cost around $1,100 to $1,400 but are expected to drop to around $200 to $300 in the coming years.[15]
- *Driver Fatigue Monitoring/Notification*: Professional drivers will be the primary market for these technologies over the coming years. Much of this technology is still experimental and utilizes eyelid monitoring to measure a driver's fatigue.
- *Tire Pressure Monitoring*: These technologies have received increasing scrutiny recently due to new legislation that will require all cars and light trucks under 10,000 pounds of gross vehicle weight eventually to be equipped with tire pressure monitoring systems. The main purpose of these systems is to warn the driver if their tires have lost air pressure, leaving the tires under inflated and dangerous.

Information Services

- *Dynamic Navigation:* Navigation technologies that use static maps or assistance from a remote concierge are commonplace in the telematics market. New technologies, however, may soon allow real-time dynamic navigation. With these devices drivers may pick the best routes to their destination avoiding congestion spots and accidents – or at least knowing that they are already on the best available route. The availability of these devices also has big implications for private sector markets.
- *Remote Mechanic – Diagnostics*: Similar to tire pressure monitoring, but more encompassing, are technologies that allow the driver or vehicle company to monitor various aspects of a vehicle's performance. These technologies promise to preempt many mechanical breakdowns that surprise car owners and drivers every year.
- *Black Box Data Recorder*: These devices monitor and record events. They are currently on the market and have been deployed in thousands of first responder vehicles across the nation. Newer versions of the technology are marketed to parents who may want to keep track of their teenagers' driving habits. The black boxes collect and record data, such as seat-belt use, speed, hard braking, hard cornering, pedal-to-metal acceleration and throttle position.

[14] *Cars With Crash-Avoidance Systems Could Save Lives*; NorthJersey.com; June 25, 2003
[15] *Cars May Soon Have Audible Rumble Strips*; The Atlanta Journal Constitution; August, 2002

Implications of Technologies for Transportation Agencies

Transportation technology is typically delivered piece by piece, whether via a consumer who purchases an automobile with new equipment or a transportation agency that makes an ITS or telematics investment. Each individual consumer must assess whether the safety, convenience, security or entertainment benefits they expect to receive will offset the price they pay for the vehicle. The transportation agency looks at each ITS investment relative to the value provided by other specific investment opportunities that it faces. These decisions can be relatively well defined.

When viewed as a system or a network, however, the potential benefits and costs change in nature and magnitude. This shift in point of view may have broad implications for how we manage and operate our transportation systems. A better understanding of these potential effects is important in helping to make decisions about potential large-scale systems such as the proposed VII. In particular, what is the overall value to public agencies and which aspects are most useful?

This section reviews the possible implications that information from system-wide investments in technology might have for transportation agencies. This review covers six major DOT functions:

- Management and operations;
- Planning;
- Design;
- Safety;
- Economic Linkages; and
- Finance.

Management and Operations

Transportation systems today face two fundamental problems: one is chronic congestion, particularly in urban areas. A second is the lack of meaningful interaction with their customers. That is, unlike most other industries, a traveler who receives poor service (misses a meeting or has a shipment delayed, for example) has no immediate recourse with the state DOT, local transportation agency or transit authority.

The menu of data that could come from full deployment of ITS, traffic probes (as an interim step) and the VII offer a chance to quantify and track performance in real time. The focus here is often on travel times, but the potential data cover much more, including weather conditions (exactly where and when is the roadway ready to freeze – or not freeze), accident characteristics (how severe was the accident and thus which type of emergency vehicle should respond), and early warning signals about congestion (as indicated by changes in headways between vehicles or a shift in braking patterns).

All of these open the door to performance-based management approaches, such as many private firms use as a matter of course. Examples include everything from the ability to track freight movements in near real time using combinations of GPS and RFID transponders as part of supply chains.[16]

Movement towards this concept is consistent with the recent emphasis on operations by DOTs and transit agencies. An important difference, however, is the new ability to measure travel times and speeds across a full range of roadways and to do so in close to real-time. These measures are closer to performance measures of direct value to travelers. Publishing these data on a regular (maybe even real-time) basis may serve to help focus day-to-day management on measures of quality as perceived by the average citizen. Most private firms already have such information and use it as part of how they manage their businesses. There can be an important feedback with customers as well if they know that "the owner" is aware of the quality of the service they receive.

In-vehicle sensors also have the potential to collect data for asset management. It is possible to equip vehicles with sensors that measure pavement conditions, for example. These data could then be incorporated into pavement management systems. One obvious advantage is that these data would be collected continuously.

Asset management is "a systematic process of maintaining, upgrading, and operating physical assets cost effectively.[17]" The ability of asset management to live up to its potential requires accurate and timely information on the condition and location of the assets. Technology can help in a number of ways. For example, roadway sign asset management has traditionally been conducted manually with visual observation by employees. Sensors and GPS technology, however, make it possible to monitor roadway sign inventories in close to real time. This method is more timely and more efficient.

Additionally, with better data, transportation agencies will be able to devise better performance measures and metrics of cost efficiency in relation to their assets. Ideally, asset management should form a multidisciplinary approach incorporating engineering, economics and business practices. Asset management then becomes an important component of the planning process.

Planning

Technologies such as adaptive cruise control and dynamic navigation enable drivers to use the road differently leading to new traffic characteristics. This will affect capacity utilization, effective levels of service, trip choice, and other factors. As these realities change, transportation planning must also change in order to capture them.

[16] GPS stands for Global Positioning System and is a satellite-based location system. RFID or Radio Frequency Identification are electronic tags or transponders that identify an object to which they are attached.

[17] http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=1130

For instance, many of the assumptions that form the basis of travel demand and planning models are likely to become obsolete as technology changes driver behavior. Consider the traditional four-step planning process of forecasting trip generation, trip distribution, mode split and trip assignment. New technologies may change characteristics within each of these steps. They can also provide more up-to-date information that make it possible to provide model updates that reflect current rather than historical traffic and location patterns.

Capacity – New technologies such as adaptive cruise control (ACC) and lane departure monitors may have big impacts on effective highway capacity. Recent research suggests that autonomous adaptive cruise control (AACC)[18] has the potential to significantly increase highway capacity. The findings of this research suggest that the way ACC technology is used is crucial to the impact of this technology.

Figure 6 shows vehicle throughput on the vertical axis and the percentage of vehicles equipped with ACC on the horizontal axis. The plotted lines represent overall capacity based upon the headways between vehicles (the time it would take for a following vehicle to reach the rear of the vehicle traveling in front of it) and based on the fraction of vehicles equipped with adaptive cruise control. With no adaptive cruise control present, vehicle throughput is around 2,100 vehicles per hour. When adaptive cruise control is introduced and calibrated to maintain a one second headway (the top line plotted) potential vehicle throughput increases, even with only 20 percent of vehicles equipped with adaptive cruise control. As the percentage of vehicles equipped with adaptive cruise control increases, capacity increases further, reaching 2,700 vehicles per hour or about 30 percent more than the base.

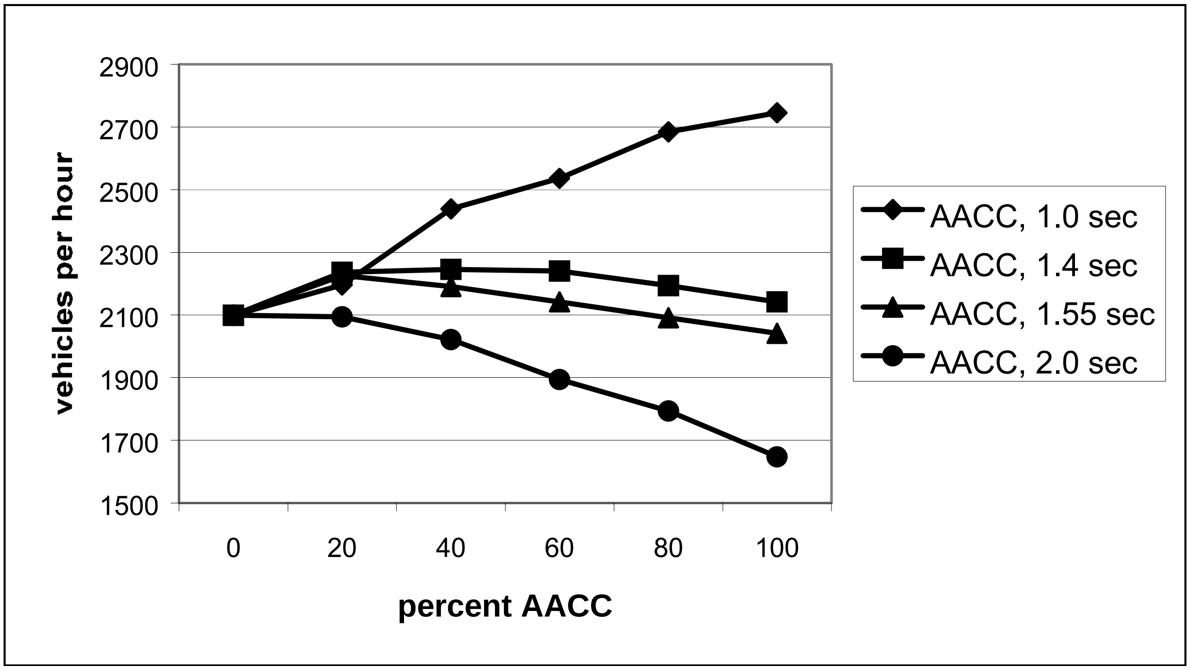
If the adaptive cruise control is set for longer gaps between vehicles (termed headways), however, effective capacity can decrease as vehicle spacing increases. The bottom line illustrates the case with headways set at two seconds. In this scenario capacity decreases as more vehicles equipped with adaptive cruise control are added to the road. This example shows that *how* a technology is used is at least as important as *that* a technology is used.

Driver Behavior – Technologies such as adaptive cruise control assist the driver in making decisions or may even make decisions for the driver. This has implications beyond capacity utilization. Models that incorporate assumptions about driver behavior may need to be recalibrated as these technologies begin to be deployed in large numbers.

Technologies can also provide new data to help improve planning. In particular, much of these data will be available in close to real-time, making it easier to track rapid changes in the location of business and individuals and shifts in travel patterns. Much of the necessary data will be provided as a by-product of other purposes, and thus should be available at modest cost.

[18] The autonomous ACC (AACC) system was intended to represent a typical first-generation product such as those now entering the market.

Figure 6



Source: Evaluation of the Effects of Adaptive Cruise Control Systems on Highway Traffic Flow Capacity and Implications for Deployment of Future Automated Systems; Kourjanskaia, Natalia; Miller, Mark A.; Shladover, Steven E.; VanderWerf, Joel; California PATH Program; 2003

Design

New in-vehicle technologies also have implications for the design of roads, much in the same way as they do for planning. For example, if adaptive cruise control allows drivers to reduce headways and still operate safely, there will be significant implications for the effective capacity of highways and perhaps for their design. An important variable here is the pace with which such devices move into the marketplace and the fraction of vehicles that need to be equipped before a noticeable effect can be seen. But, since planning and design both look to future requirements, we need not wait to see the full effect before reacting.[19]

One instance where this has been explored is the design of truck-only lanes. The design of truck-only lanes typically necessitates two lanes since an accident in a single lane could cause a significant and costly backup. Due to limited space, constructing truck-only lanes to these specifications on SR-60 in Los Angeles County was estimated to cost approximately $4.3 billion. Much of this high cost resulted from design constraints where SR-60 interferes with the truck lanes. The use of automated truck lanes would reduce the initial capital costs to $1.4 billion. These automated truck lanes would only

[19] For example, most DOTs have adjusted the standard capacity of a lane in recent years from 1800 vehicles per lane per hour to 2000 or more based on the observed ability of new models to reduce headways because of more powerful engines and better braking systems.

require one lane since they automate all aspects of driving the vehicle while on the facility.[20]

Assumptions regarding driver behavior are of critical importance in highway design. Engineers strive to design a road that is both safe and offers the best mobility possible. These two interests are often in conflict and roads designed for higher speeds require lower grades, wider shoulders, more gradual curves and greater lines of sight in order to meet safety standards. Designers are also constrained by land characteristics and available funds. Highways designed at higher speeds generally use more land and land in long, straight paths. New transportation technologies, however, may make it possible to ease design constraints by allowing vehicles to navigate points safely that would be considered design exceptions. Table 7 illustrates some conventional tools and strategies to deal with design exceptions and compares them to various technological solutions.

Vision enhancement devices, for example, allow users to see the road in different ways, identifying and illuminating signs and other objects and even allowing drivers to "see" through inclement weather and around curves. Although still being defined, these technologies could have major impacts on geometry and other aspects of the roadway.

Table 7. Technological and Conventional Tools for Mitigating the Potential Safety Risk from Design Exceptions[21]

Design Exception	Conventional Mitigation Tool	Technology Tool
Narrow Lanes or Shoulders	• Pavement edge lines • Raised reflective markers • Delineators • Shoulder rumble strips • Centerline rumble strips	• Lane departure warning system
Steep Sideslopes, Roadside Obstacles	• Roadside object markers • Slope flattening • Rounded ditches • Obstacle removal • Breakaway safety hardware • Guardrail or crash cushions	• Driver vision enhancement • Lane Departure System • Dynamic Navigation System
Narrow Bridge	• Approach guardrail • Pavement edge lines • Warning signs and/or object markers	• Collision avoidance system • Vision Enhancement
Limited Sign Distance at Crest of Vertical Curve	• Advance warning signs • Obstacle removal • Shoulder widening • Driveway or intersection relocation	• Adaptive Cruise Control • Vision Enhancement

[20] *State Route-60 Automated Truck Facility Study*; Sarakki Associates for California Department of Transportation; Working Draft; September, 2003
[21] Adapted from Table F-16 in *A Guide to Best Practices for Achieving Context Sensitive Solutions (CSS)* NCHRP Report 480; Section F: Ensuring Safe and Feasible Solutions.

Sharp Horizontal Curve	• Advance warning signs • Shoulder widening and/or paving • Improved superelevation • Transverse rumble strips or pavement markings • Slope flattening • Pavement and anti-skid treatment • Guardrail or crash cushions	• Adaptive Cruise Control • Lane Departure System • In-Vehicle Navigation
Hazardous Intersection	• Upgrade intersection traffic control • Warning signs • Street lighting • Pavement anti-skid treatment • Sight distance improvements	• Collision avoidance system • Adaptive Cruise Control • Vision Enhancement

Economic Links

Today's economy is dominated by services and light manufacturing. This means that the movement of people and goods has high value and that timely arrivals and departures are more important than a generation ago when we measured success in terms of ton-miles or vehicle miles. Part of this concept is captured in the phrase "supply chain logistics," but the implications go beyond the reliable movement of goods worldwide. The ability to attract a skilled and cost-effective labor force faces some of the same problems as a supply chain system.

The ability to collect real-time performance information on all roads – and the parallel ability to make short-term forecasts of travel times -- opens the door to new ways for DOTs to work directly with business. An active sharing of information on system performance, including actions by the public sector that could affect that performance, may make it possible to work with major shippers on when they move goods or schedule shifts. Such active management would work best if there were reliable measures of travel times so that performance could be tracked.

Combining financial incentives with performance measures would help – at what point is it more cost-effective for a DOT to reduce registration fees (or simply write a check) for businesses that schedule movements to maximize the effective capacity of the system. Of course, this is easier said then done – witness the problems the Ports of LA and Long Beach have had in encouraging container traffic to shift to off-hours when plenty of highway capacity exists.

Finance

The technology exists to implement variable roadway pricing, with charges based on where and when one travels. Traditionally this has been promoted as a way to discourage travel in certain areas – as with the current London congestion system.

Another approach would be to link payments with a guaranteed level of service – perhaps even including the classic private-sector offer of a money-back guarantee. Speed will always be above 50 miles an hour, for example. This would provide travelers with something for their money, rather than what is often perceived as a motor fuel tax in disguise. Revenues could be large, but the economic and social gains from never being late when it really mattered would likely be larger still.

Experience in Southern California with SR-91 between Orange County and San Bernardino County and the San Diego HOT lanes (high-occupancy toll lanes) provide evidence that people are willing to pay more for trips that matter. Both these projects are toll roads that vary the rate (price) according to the amount of traffic in order to provide travelers with a consistent level of service. This parallels what many private businesses do now, although it is relatively new in highway transportation. Rates vary widely during the day, from 25 cents at night to $4 or $8 during peak periods. S.R. 91 has been studied extensively. Despite the high tolls and the availability of "free" but congested lanes, usage matches that of the general population – or at least those who normally travel the corridor. Most commuters use the high-priced lanes once or twice a week.

Such a concept has many barriers to overcome, starting with political ones. Nonetheless it is a logical extension of the service orientation that the new data will support.

Safety

Safety is often cited as the number one priority for federal, state, and local transportation agencies. Technology, in the form of ITS, is a tool that has been used for a number of years to make the nation's roads safer. In-vehicle technologies and infrastructure-vehicle communication has the potential for even greater safety benefits.

Already, there are a number of in-vehicle technologies available in the marketplace (or coming soon) that make driving safer. Many of these will be installed in vehicles based on consumer demand:

- Hazard warning systems – improves safety by detecting objects near the vehicle and alerting the driver through audible or visual signals.
- Adaptive cruise control – enhances driver safety and convenience by automatically adjusting vehicle speed during cruise control operation to keep from encroaching to closely on slower vehicles ahead.
- Collision avoidance features – improves safety by over-riding dangerous maneuvers by the driver and taking active control of vehicle direction and speed to avoid accidents.
- Vision enhancement – improves safety by providing images of objects beyond the driver's normal field of vision during nighttime or inclement weather.
- Driver drowsiness warning – improves safety by reducing incidents of drowsy, non-attentive driving
- Crash safety management systems – optimizes the performance of active safety features in the vehicle by taking pre-emptive action, adapting seatbelt and airbag

deployment to the characteristics of each passenger, and coordinating the actions of various safety systems.

The public sector can work with these features and add additional safety values by installing compatible infrastructure. The type of infrastructure installed will likely vary from location to location, although most will depend on effective means of communication between vehicle and roadway. Road intersections are one logical choice and are a major focus of FHWA's vision for the VII. The public sector can install infrastructure that alerts drivers to the presence and location of other drivers, helping coordinate the safe flow of traffic.

The public sector could also significantly reduce accidents and injuries from accidents through in-vehicle technologies providing that there is the political will to do so. For instance, the government could mandate the OEMs build into cars devices that would render a vehicle inoperable if the driver was intoxicated.

Next Steps

You've got to think about big things while you're doing small things, so the small things go in the right direction – Alvin Toffler

The result of technological applications in transportation is not clearly defined. Although a national program exists, it often seems to be carried out in a disjointed fashion. It is unclear if improvements in one corner of the nation have anything to do with what is going on elsewhere.

New technologies in combination with a new interest in a national perspective can help to speed deployment of transportation-related technologies and do so in a way that allows both public and private entities to take full advantage.

While many details will vary, three primary characteristics appear essential for a future system that can create a "virtuous cycle" of productivity growth similar to the successes of past generations:

National Scale – Although discrete technological deployments are usually beneficial, a system-wide deployment should generate much higher returns and benefits. This is analogous to the Interstate Highway System or the internet. A system also supports economic stimulus from economies of scale and the seamless use of standard technical components.

Assured Finances – A future system should have an assured financial mechanism. This need not be as grand as the Highway Trust Fund, of course, but a well-defined and reliable source of funds provides the assurance that private and public entities need in order to make ambitious changes. While almost anything planners may dream up is possible (as long as it conforms to the laws of physics), as a society we prefer options where scarce resources are spent in the most effective way. This aspect may be the difference between a nationwide Automated Highway System requiring huge amounts of capital and maintenance and a system that emphasizes a more commercial approach.

Rapid Deployment – Resources will be used more efficiently and cost effectively if they bring a system to deployment rapidly. There is a close linkage here with an assured source of funding.

Define Broadband Wireless Network

A key to the success of VII is an effective means of communication between the vehicle and the infrastructure and among vehicles. This should be:

- Near universal – 10 percent of highway miles accounts for 80-90 percent of vehicle miles traveled, so we need not cover everything
- Continuous – once on the road, gaps are undesirable
- Always on – no waiting for the network to be ready
- Low-cost – at least very low marginal cost once the network is in place
- Non-prescriptive – that is, easy for suppliers and other firms to adapt to the technology (the internet and the Interstate offer good examples)

A group of wireless technologies are candidates to meet these needs, including: DSRC; 802.11 a, b, g, (WiFi, WiMAX, Mobile-Fi); Digital Cellular/PCS/2.5-3G; Ultra Wideband; and Infrared.[22]

In all likelihood, these communications technologies would work together in some combination. As with any national infrastructure project, significant engineering details need to be solved. Depending on the technology selected, using highways as the backbone could support adjacent non-mobile business activity, with broad economic and social implications..

Business Case

Who does what in a new public-private partnership? What are the characteristics of such a partnership for a transportation communications system and what roles will the public and private partners play? Although important institutional roles remain undefined:

The public sector could provide:

- Access to rights of way across the country. Shared resource deals show that barter works better than cash, with DOTs receiving communication services and access to floating car data.
- Access to power. Urban areas and rural interchanges have light poles and traffic lights which offer power and places to locate communications equipment.
- Access to backhaul telecommunications – at least where fiber optics are in place.

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[22] The differences among these technologies are confusing to all but a few experts. The key lesson is that many options exist, with many specific applications. The market has yet to sort out the winners and losers.

- Soft loans. TIFIA (a federal bank for infrastructure) is an option and many states have their own State Infrastructure Banks. Their basic structure makes these tools attractive for businesses with unproven markets.
- A customer – DOTs need traffic information that only vehicle probes can provide and it may be more cost-effective to purchase data rather than install more sensors..

The private sector could:

- Provide technical knowledge
- Construct and operate the network
- Fill in places not covered by the backbone.
- Market commercial services
- Provide part of the capital, including repayment of public loans

Public-private partnerships of this scale do not happen automatically. Usually, one partner takes a lead role. In the case of the Interstate Highway system this was the federal government; for transcontinental railroads, it was the private sector. Given the technology involved, an integrated national wireless network probably requires leadership by the private sector. Speed argues for a small number of firms, rather than a consortium. An active public sector role is required as well. Given the important role played by access to highway rights of way, AASHTO is a necessary partner.

Corporate Culture

The changes discussed here imply a more business-like management style for many transportation agencies. Managers will now be held accountable for changes in travel times and related performance – timely response to incidents, for example. The concept of showing the public data on how well the highway and transit system performs is new. Private firms do this, but not more often than quarterly financial statements.

The pace of technology change is faster than the normal pace at which we change transportation policies and investments. Success will require finding more than a few advocates for change within the DOT.

Regulatory and Related Issues[23]

<u>Liability</u> – A number of liability issues come into play with the transportation technologies discussed here. These may slow down or impede deployment of a system or technology. Product liability is a common concern. Since many of these new technologies make decisions for drivers, malfunction could be a matter of life and death, or at least accident or injury. A second liability issue concerns public and private sector liability for faulty data. If drivers and businesses make decisions based on information supplied from a state DOT, for example, is the DOT liable for decisions that driver might make based on these data? What if those decisions lead to an accident?

[23] These issues are discussed in more detail in "Technology and the 21st Century Vehicle," prepared by Weiland Consulting Group for Hudson Institute, (2004). In some ways, the Weiland Report acts as a companion piece to this document.

Economic Regulation – The types of relationships and partnerships likely to evolve from an integrated national transportation technology infrastructure may differ distinctly from prior partnerships. For example, what if the public sector partners exclusively with one technology provider or limits the number of providers with whom they work? Also, revenue sharing between the public and private sector tends to draw scrutiny. Laws with respect to many regulatory issues may vary from state to state, having the potential to impede nationwide systems.

Safety – As debate over in-vehicle use of cell phones shows, technology can be a distraction. This is especially true for entertainment technologies such as m-commerce, mobile-email, video and games. While these features are not developed for use by the driver, their abuse is a safety concern and a liability concern.

Privacy and Use of Data – The American public has a long history of being suspicious of "Big Brother." Moreover, due to email spam and annoying calls from telemarketers, there has recently been a backlash against how the private sector uses personal data. For many of the new technologies discussed in this paper, 'data' is a defining characteristic. Users will naturally wonder what is being done with the data collected from them. There are considerable privacy concerns and the public will need to be educated on exactly how their data is used. The public and private sector also need to define what the proper uses are for data that could be employed in services different from the original intent (such as solving crimes).

Privacy issues reflect both perception and reality. The importance of the former means that public and private entities take this issue seriously, even where legal restrictions are not binding. Wireless firms in particular are concerned about these issues. This, in turn, has slowed the deployment of some potentially useful technologies and may stop some altogether. Indeed, uneasiness about technology has been a major stimulate to privacy concnerns.

Appendix A

Glossary of Relevant Terms

Except where otherwise noted transportation related definitions are from FHWA and telecommunications definitions are from the Federal Communications Commission. Terms marked by an asterisk are from the authors of this paper.

Asset Management*

A systematic process of maintaining, upgrading, and operating physical assets cost effectively.

Backhaul Telecommunications*

Transmitting data to a network backbone.

Broadband

High-capacity high-speed, transmission channel carried on coaxial or fiber-optic cables with a wider bandwidth than conventional copper telephone lines. Broadband channels can carry video, voice, and data simultaneously.

Congestion Pricing

The policy of charging drivers a fee that varies with the level of traffic on a congested roadway. Congestion pricing is designed to allocate roadway space in a more efficient manner. Congestion pricing is also known as relief tolling, variable pricing, and road pricing.[24]

Dedicated Short Range Communications (DSRC)

Technology that allows high-speed communications between vehicles and the roadside, or between vehicles, for ITS; it has a range of up to 1,000 meters. DSRC applications include electronic toll collection, and electronic credentialing and monitoring of commercial vehicle operations (CVO).

Dynamic Navigation*

The use of real-time traffic information to guide drivers along the fastest route to their destinations.

Floating Car Data (FCD)*

Entails recording traffic data from vehicles that "float" with traffic and serve as measuring stations. Devices on the vehicles record and transmit variables such as speed, position and direction of travel.

Global Positioning System (GPS)

Satellite-based radio positioning systems that provide 24 hour three-dimensional position, velocity and time information to suitably equipped users anywhere on or near the surface of the Earth.[25]

[24] www.i35waco.com/documents/glossary.shtml

[25] www.mobileworld.org/glossary.html

High Occupancy Toll (HOT) Lanes

Limited-access, normally barrier-separated highway lanes that provide free or reduced cost access to qualifying HOVs, and also provide access to other paying vehicles not meeting passenger occupancy requirements.

Intelligent Transportation Systems (ITS)

The development or application of technology (electronics, communications, or information processing) to improve the efficiency and safety of surface transportation systems.

Original Equipment Manufacturer (OEM)*

Refers to the company that acquires a product or component and reuses or incorporates it into a new product with its own brand name.

Performance-Based Management*

Using performance measures to carry out and evaluate management.

Performance Measures*

Any measure designed to quantify how well or how poorly an organization performs. They provide a series of indicators, expressed in qualitative, quantitative or other tangible terms, that indicate whether current performance is reasonable and cost effective.

Real-time information*

Pertains to a data collection, processing and output occurring no later than the time when these are needed for effective control.

State Infrastructure Bank

An infrastructure investment fund established to facilitate and encourage investment in eligible transportation infrastructure projects sponsored by public and/or private entities.

Supply-Chain Logistics*

Management of a network of retailers, distributors, transporters, storage facilities and suppliers that participate in the sale, delivery and production of a particular product or products.

Telematics

The usage of computers and telecommunications devices in vehicles.

Transportation Infrastructure Finance and Innovation Act (TIFIA)

Federal credit program under which the U.S. Department of Transportation that may provide three forms of credit assistance – secured (direct) loans, loan guarantees, and standby lines of credit – for surface transportation projects of national or regional significance.

Traffic Probes*

Vehicles equipped with sensors or other devices (e.g. cell phones) that serve as data points. See “Floating Car Data.”

Variable Roadway Pricing

See “Congestion Pricing”

Vehicle Infrastructure Integration (VII)

A USDOT initiative that builds on the research and operational tests conducted under the Department’s Intelligent Vehicle Initiative. Vehicle manufacturers would install the technology in all new vehicles, beginning at a particular model year, to achieve the safety and mobility benefits while, at the same time, the federal/state/local transportation agencies would facilitate installation of the roadside communications infrastructure. Vehicles would serve as data collectors, transmitting traffic and road condition information from every major road within the transportation network. Access to this information will allow transportation agencies to implement active strategies to relieve

Appendix B

Details on Vehicle Technology and Deployment

Category	Type	Technology	Deployment Data
Safety and Security	Crash Avoidance	Adaptive Cruise Control Maintains a certain distance - set by the driver - from the car in front.	● Within three years, DOT officials say, some cars will be sold with radar systems that allow drivers to avoid rear-ending other cars, computers that tell motorists they are drifting in and out of lane, and systems that will warn of impending accidents at intersections. ● A prototype built by General Motors and the DOT cost about $100,000. Safety options would have to cost hundreds, not thousands, to woo the car-buying public, officials acknowledge. ● General Motors has installed a full-blown collision-avoidance system in 80 Buick LeSabres, complete with radar, road sensors, global positioning, and adaptive cruise control. The cars began a year of testing in March on Michigan roads.
Safety and Security	Crash Avoidance	**Throttle Controller** - Receives signals from a radar system in the car and increases or decreases the car's speed to maintain distance from the car in front.	
Safety and Security	Crash Avoidance	**On-board radar:** A radar system in the grille senses the distance to the next car and triggers warnings - such as audible alarms or lights - for the driver. Some manufacturers, such as Honda and Toyota, are beginning to offer this in Japan.	
Safety and Security	Crash Avoidance	**Lane mapping**: Sensors scan the road for changes in color, essentially picking up lane lines on the dark pavement. A computer takes the data and figures out if a driver is drifting in and out of the lane. On-board displays warn the driver of the drift.	
Safety and Security	Automated Highways	Automated Lanes	● Reduce traffic congestion by having big rig trucks rolling in tandem alongside California freeways, their speed, steering and braking operations controlled every 300 meters by dedicated short-range communications devices permanently embedded in the pavement. ● The automated lanes project should be underway in 2005, and operational two years later once the 37-mile long lanes have been constructed.

Safety and Security	Automated Highways	Automated Car	● Most say it's hard to pin down when self-driving vehicles might become reality. The University of Washington's Dailey says it shouldn't be calculated in years but in engineering cycles, currently about three years from concept to production. His estimate: "I would guess it would be about ten car cycles before you see anything resembling autonomous driving."
Diagnostic Services		Remote Mechanic	● Critics have generated a lot of heat rebutting the supposed benefits of remote diagnostics: They say that the data, for what good it does to have it, is not worth paying for. Or, remote diagnostics typically does not tell the technician why the vehicle is down (perhaps remote diagnostics should have been called remote symptomatics). And when a fault code is detected, should a technician be dispatched to the truck to figure out what problem has caused the fault code, should the truck head to the nearest garage, or should the truck simply go about its business and get looked at the next time it is at the shop?
Safety and Security	Vision Enhancement	Cadillac's Night Vision (Infrared)	Cadillac's DeVille has a $2,250 night-vision system that allows drivers to see images beyond the reach of headlights. The system, the only one offered by any automaker (March 2003), uses thermal imaging, which tracks heat sources. Infrared cameras define the scene by detecting radiation from or emitted by various objects within the field of view. Roadway environments are dominated by traces of this visible and thermal radiation. Many types of imaging systems are currently in development, and these systems are generally defined by the varying transmission bands in which they operate and the optimal distance that it can detect radiation (Near Infrared, Medium-Range Infrared, and Long-Range Infrared). The simplest form of imagers are the Visible/Near infrared systems. Fortunately, these systems are commercially available and easily adaptable to many applications related to ITS and vision enhancement. The imagers detect the inherent thermal signature of radiating objects. These images can then be presented on a head-up display (HUD) inside the vehicle. Other car manufacturers are developing systems based upon radar and UV light.
Safety and Security	Vision Enhancement	Radar Enabled Systems	Radar detection is also being studied in hopes of possible application toward vision enhancement systems. The benefit of such a system is that it is an all-weather technique, unlike infrared detection, which can be degraded by weather. Active radar imaging systems use their own source of illumination by transmitting millimeter-wave energy, which can travel through rain, snow, fog, etc. The reflected energy is detected by the radar, and images are reconstructed by means of a signal processor. A HUD may then be used to show the driver the locations of obstacles by projecting a symbol overlay onto the windshield.

Safety and Security	Vision Enhancement	UV Light Enabled Systems	Another technology being applied toward vision enhancement systems are ultraviolet headlights. Although quite simple, the system has shown itself to be successful in improving sight distance and detecting obstacles and other hazards, and does so at a minimal cost. UV high-beam headlights are paired with normal low-beam headlights and can increase visibility range at night up to 200m. Since UV radiation is virtually invisible to the human eye, the UV headlights do not cause blinding glare to oncoming traffic. The lighting system augments the brightness of fluorescent pigments embedded in many objects in the road environment, making them more visible to the driver.
Communication	on-line access	In-car communications with on-line access	In April 2003, BMW claims to be launching the world's first in-car communications centre featuring on-line access. Acting like a newspaper, on-line directory, personal assistant and virtual co-driver all rolled into one, this latest breakthrough allows drivers and their passengers to stay 'in touch' anywhere in the UK.
Diagnostic Services	Tire Pressure Monitoring	Tire Pressure Monitoring Systems	The U.S. government has passed legislation that requires all passenger cars and light trucks under 10,000 pounds of gross vehicle weight to eventually be equipped with tire pressure monitoring systems. The main purpose of these systems is to warn the driver if their tires are losing air pressure, leaving the tires underinflated and dangerous. The National Highway Traffic Safety Administration (NHTSA) provides vehicle manufacturers two options to comply with the law. The first is to install a direct tire pressure monitoring system that warns drivers when the air pressure in any of their tires drops at least 25% below the recommended cold tire inflation pressure identified on the vehicle placard or owner's manual. The second is to install an indirect tire pressure monitoring system that would warn the driver when a single tire has lost at least 30% of its inflation pressure compared to the other tires on the vehicle. The two systems have different warning thresholds because the indirect systems cannot offer the same information or accuracy of the direct systems.
Safety and Security	Crash Avoidance	Safe Trac Lane Tracker	A vision-based lane tracking system developed under DOT sponsorship by AssistWare Technology and Carnegie Mellon University. The unit is a small oblong box that can be mounted on the dash or headliner. It has two readouts that alert the driver when his vehicle moves from the lane center. The system uses a camera to detect a variety of signals from the road that delineate lanes. It primarily uses center lane markings, but it is capable of using oil drops, occasional small retro reflectors or snow ruts when lane markings disappear. SafeTrac operates effectively in over 97 percent of highway conditions and gives false alarms less than once in every eight hours of driving.

Safety and Security	Crash Avoidance	Driver Fatigue Monitoring/Notification	Of the drowsiness-detection measures and technologies evaluated in this study, the measure referred to as “PERCLOS” was found to be the most reliable and valid determination of a driver’s alertness level. PERCLOS is the percentage of eyelid closure over the pupil over time and reflects slow eyelid closures (“droops”) rather than blinks. There is not much evidence that driver fatigue notifications systems are currently commercially available. Primary market will probably be for professional drivers.
Safety and Security	Crash Avoidance	Actigraph sleep activity monitor	The Actigraph sleep activity monitor, or ‘sleep watch’ provides both a sleep profile and a performance profile. The watch provides a time display and is worn on the wrist. It measures the activity of the wearer, both when sleeping and awake. When a wearer is asleep, the watch relates the measure of activity to a mathematical algorithm based upon a pre-existing standard of sleep. At the touch of a button the watch will then read back to its wearer the length and quality of his sleep as a percentage of available energy. There is a direct relationship between the amount of movement and the quality of sleep. This relationship makes it possible for the watch to determine sleep quality. Much like a fuel gauge, the watch will show sleep as a reservoir, which is drained by activity, making the readout easy to understand.
Safety and Security	Crash Avoidance	Lane Departure System	AutoVue is already on more than 3,000 commercial vehicles and is expected to make its way into the passenger car fleet in the near future, with one Japanese automaker reportedly close to announcing a major contract to incorporate it into new luxury models. If a truck with AutoVue strays onto a painted line, the system emits the same sound a tire makes when it hits a rumble strip. Significantly, the sound comes from a speaker on the same side of the vehicle as the lane departure. It is disabled by use of the turn signal, in itself a useful contribution to highway safety in an age when too few drivers signal their intentions. It costs $1,100 to $1,400 a unit, a price Memole predicts will fall to between $200 and $300 when mass-produced for automobiles. Memole predicts lane departure systems will be a common auto option within 10 to 15 years.
Safety and Security	Crash Avoidance	Lane Departure System	Delphi's vision-based Lane Departure Warning technology will warn the driver should the vehicle start to drift out of lane, helping to greatly reduce one of the largest causes of vehicle collisions. The system can be used as a stand-alone safety aid or integrated with other safety systems as part of Delphi's Integrated Safety Systems strategy.

Information	Driver's convenience	Gesture interfaces for Automotive Control	Although hand gestures and driving are typically thought of only in the context of fists and extended middle fingers, researchers at Carnegie Mellon University (CMU) have a slightly different perspective, one that could result in improved use of the various functions in a vehicle without driver distraction (a cause, of course, of the aforementioned fists and fingers). "Turning knobs and pressing buttons and even stepping on the brake or accelerator are all gestures, so we use them to control everything in the car," says Tsuhan Chen, professor of electrical and computer engineering at CMU.
Safety and Security	Vision Enhancement	Heads-Up Display	DOT research contributed to the accelerated commercial deployment of introduced in the 2000 Cadillac DeVille, and is now available on other GM models. In the winter of 2001-2002, another promising military vision enhancement technology was field-tested with support from IVI: the "Head-Up Display (HUD)," a technology developed for military jet aircraft. The HUD projects a visual display on the driver's field of view that depicts road boundaries and any obstacles in the vehicle's path, based on a geospatial database and radar obstacle sensing.
Safety and Security		Air Bag Deployment Notification	Description: In the event that your front air bags deploy, your vehicle will send a signal to the OnStar Center. Benefit: An Advisor will attempt to contact you, inquiring whether or not you need assistance. If you can't answer, emergency help will be notified and your location will be provided.
		Emergency Services	Description: If you find yourself in an emergency situation, simply press the red emergency button. Your location information is transmitted to the OnStar Center and your call takes priority status on an Advisor's screen. Benefit: Within seconds, an OnStar Advisor can contact the nearest emergency service provider with your location and your request for help.
		Stolen Vehicle Tracking	Description: If you determine that your vehicle has been stolen, contact an OnStar Advisor. OnStar will help the police determine its whereabouts. Benefit: You'll be prepared and have a better chance of recovering your vehicle if you're one of the millions of people who experience car theft every year.
		Remote Door Unlock	Description: Just give the Advisor your PIN and they'll send a signal to unlock your door (if available on your vehicle). You can even have it delayed up to 15 minutes to give you enough time to get to your vehicle. Or, if you remembered that you forgot to lock your doors once you're away from your vehicle, an Advisor can send a signal to lock them for you (if available on your vehicle).

Safety and Security			Benefit: You'll have quicker and easier entry into your vehicle if keys are locked inside and the reassurance of a locked vehicle while you're away.
		Driving Dirctions	Description: Not everyone likes to admit when they're lost, but then, not everyone has OnStar. Helpful Advisors with current digital maps are a better way to make sure you're headed in the right direction. Upon your request, they'll use a global positioning system to locate your vehicle and give you clear directions to your destination or guidance to nearby hotels, ATMs, etc. Benefit: Get directions without stopping. Plus an Advisor may stay on the line until you find your way, so you don't have to worry about remembering road names or turns or ever pull over to write it down.
		Roadside Assistance	Description: Whether you need gas, a tire changed or your car towed, an OnStar Advisor can contact help. Plus, they can notify a friend or relative to let them know you'll be on your way shortly or that you'll need a ride. Benefit: By being able to provide your location, OnStar can aid you in a variety of unfavorable situations. This service gets even better when it's teamed with Ride Assist, included in the Directions & Connections as well as the Luxury & Leisure subscription packages.
		GM Goodwrench Remote Diagnostics	Description: If your "Check Engine" light comes on or you hear a strange noise coming from under the hood, an Advisor can remotely check it out*. They can even schedule a service appointment for you. Benefit: You'll know immediately whether you should continue driving or find a safe place to stop while you wait for assistance.
		Personal Calling	Description: Make and receive calls in your vehicle with a fully integrated, hands-free, wireless phone that uses voice-activated commands. You'll also receive Virtual Advisor which lets you track your portfolio with stock quotes and investment tools provided by Fidelity Investments, get the latest news updates or hear your daily horoscope and stay in tune with the weather, traffic and your favorite sports teams. You can even listen to your email and reply from your vehicle. Benefit: It's there for you just in case your hand-held cell phone is lost, forgotten or has a low battery. No activation fees. No additional long distance or roaming charges and no additional wireless equipment. Even better, there's no wireless equipment to purchase or keep track of. These voice-activated tools keep you safely connected to the outside world while driving.

		Information/Convenience Services	Description: From suggesting a hotel to assisting with the reservations, your Advisor can help with a host of convenience services. Advisors can direct you to the nearest ATM, gas station, restaurants and more. Or have them look up a specific company and they'll tell you its location. Benefit: Advisors access a database of over 7 million service listings — all updated regularly, so you'll receive the most current information available.
		Remote Horn & Lights	Description: OnStar can flash your exterior lights (headlamp and/or parking-lamp flash varies by vehicle) and sound your horn if you are having trouble locating your vehicle. Benefit: An added security feature and a faster way to locate your vehicle.
		AccidentAssist	Description: An Advisor can contact your insurance company, police and other emergency services and even a friend or family member if requested. Furthermore, they have developed a "best practices" list together with leading insurance companies to assist you through most accident situations. Benefit: An Advisor will make sure you're okay, help you stay calm and guide you on what to do.
		RideAssist	Description: Should you or your vehicle not be suitable for driving, an Advisor can call a taxicab* at your request. If no cab is available, we will try to contact a relative or friend. Benefit: A safer and more reliable way to make it home.
		Online Concierge	Description: Find recommendations to entertainment, restaurants and shopping for a number of cities around the world. Log on to OnStar's Online Services and simply select a city, choose a category and search our database for the most frequently asked concierge questions. If you don't find the information you need, email the online concierge. A local city expert will email you back. Benefit: OnStar gives you one source for credible answers with a database of unique recommendations and information for 52 major U.S. and international cities.
		Personal Concierge	Description: Want hard-to-get tickets or just remembered your mom's birthday is today? OnStar's personal concierge service helps make you the hero. Benefit: Our Concierge Advisors are specially trained and well connected to make all the arrangements you need — at home or on the road. This service is only a button away with the Luxury & Leisure Package.
Entertainment	Telivision	Digital Telivision	As of October this year, Mercedes customers will be able to receive digital TV channels whilst on the move. The Stuttgart car brand has developed a digital receiver capable of retrofitting to E, CL, S and SL-Class models, and which is available from Mercedes-Benz sales and service outlets and sales partners.

Information Services	Dynamic Navigation	Low level "real time" dynamic navigation	Users of Windows Mobile-based Pocket PC users can wirelessly access location-based services to find destinations, save driving time and enhance their over-the-road travel safety, improving mobility across America. Aggregating up-to-the-minute highway monitoring data from various State Transportation Departments and its partners, Pharos' Smart Traffic provides travelers true real-time, traffic-flow information and options to avoid traffic congestion. "Integrating real-time traffic information into navigation systems will assist travelers in selecting the best travel choices and lead us to a new level of transportation efficiency," according to Neil Schuster, president & CEO of the Intelligent Transportation Society (ITS) of America.
Information Services	Dynamic Navigation	Navigation Technologies Trial	Navigation Technologies, a leading provider of digital maps for vehicle navigation, Internet/wireless, government and business solutions, and TANN, a leading provider of real time traffic and travel information, are collaborating on a four-city trial of Navigation Technologies' real-time traffic data solution for North America. The trial is currently underway in Chicago, Los Angeles, New York and Detroit. Navigation Technologies has developed a traffic data solution designed to aggregate the data of multiple leading traffic data providers, like TANN, to provide the highest quality real-time traffic information. The information is packaged for delivery to vehicles and wireless handheld devices to help drivers in North America make smart routing decisions. The solution is uniquely designed to provide detailed traffic information aggregated specifically for navigation applications. It utilizes multiple sources and types of information from incident (accidents, stalled vehicles, etc.) and flow (speed and movement of traffic) to weather and events. The information is merged with NAVTECH® map data through a data integration process for delivery to an in-vehicle navigation system, PDA or mobile phone through a wireless signal.

Entertainment	Concierge Service	Mobile Concierge delivered over PDA with info for 25 cities	Sept. 10 /PRNewswire-FirstCall/ -- Nissan is harnessing the power of the AvantGo® mobile Internet service to extend its "Shift_" campaign to mobile and wireless devices. Nissan has launched a pioneering affinity marketing campaign for the Nissan 2004 Maxima called the "Mobile Concierge" that packages advertising for the new car with compelling entertainment content for consumers. The Maxima Mobile Concierge includes restaurant, nightlife, hotel, business service, museum listings and other localized information licensed from 10Best, an award-winning premium destination content company. Consumers can now access information for the 25 top U.S. cities and vacation destinations via their personal digital assistants, or PDAs. According to Peter Marcin, Maxima marketing manager at Nissan North America, Inc., "AvantGo is the perfect cutting-edge technology to reach an upscale audience of nine million. With the Mobile Concierge, we're offering comprehensive entertainment information to consumers, while presenting the 2004 Maxima on a unique mobile platform, complete with its hip, sleek branding intact. Sales volume of the new model has already been notable among both new and previous Maxima drivers."