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Publication Date

2001-05-01

Revised May 2001

**Transportation Technologies:
Implications for Planning**

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Summary

Transportation is rapidly being changed by new technologies, such as Intelligent Transportation Systems (including smart cards, on-board diagnostics and information systems, and smarter highways, transit, automobiles, logistics systems, and other information systems). The range of options and their impacts will continue to expand as new technologies are introduced over the next two decades, and may alter transportation systems in many ways. For example, electric, hydrogen, or hybrid electric-petroleum vehicles may be introduced that would substantially alter emissions and fuel characteristics of the fleet, and potentially pose challenges in terms of system operations and finance. Smart card technologies could greatly improve the feasibility and convenience of a variety of pricing options for road use, parking, and transit fares. Monitoring and information systems could enable travelers to time trips and select routes to avoid congestion, reducing it in the process. Advanced traffic management systems could increase road capacity significantly while improving safety and respecting other objectives such as pedestrian comfort. Over the longer run, automation could make order of magnitude improvements in safety, capacity, and convenience.

Whether and to what extent these technologies become a significant element of the transportation systems will depend, however, not only on technological developments but on both public and private decisions about the technologies' desirability and usefulness. System-wide applications and high market penetrations of new technologies are likely to have vastly different benefits and costs than the piecemeal applications that are currently proceeding.

Introduction

Historically, transportation has been a technology intensive industry, and over the years advances in science and technology have produced numerous improvements in transportation systems. In the last several decades, new technologies have been applied to the management of such diverse problems as traffic congestion, air pollution, fuel use, and accident risk, both for passenger and freight transport. As a result, users have benefited from:

- Decreasing travel costs
- Increased or stable travel and transport speeds, despite large growth in transport volumes
- Low cost same-day, next-day, and just-in-time deliveries
- Safety, security, and reliability improvements
- More comfort and convenience
- Higher energy efficiencies (though much of this gain has been absorbed in producing bigger and more elaborately equipped vehicles rather than fuel use reduction)
- Declining environmental impact, especially in the form of air pollution and noise emissions
- Increased capacities per vehicle.

In the face of substantial growth and change over the next two decades, the challenge will be to continue to deliver the benefits of a well-managed transport system.. Technological innovations will certainly be integral to this effort. Continuing research and development in materials and processes and in computers, telecommunications, and operations now offer dramatically expanded possibilities for efficiently moving people, goods, and ideas. At the same time, technological changes may be altering travel patterns, travel behavior, and travel choices in ways that are not completely understood at present, so part of the policy challenge will be to continue to monitor emerging patterns of growth and change.

This paper addresses several key technological changes that could have important impacts on the transportation systems of the United States. The paper does not attempt to be exhaustive – that would require book-length treatment of the subject. Rather, the paper addresses several key technological changes that could alter needs and options and thus should be considered in planning the transportation systems of the next two decades. The technologies considered here are:

- Telecommunications and Information Technologies (IT) – mobile phones, the Internet, and their travel effects
- Intelligent Transportation System (ITS) – smarter vehicles, highways, and monitoring systems
- New systems –alternate fuels and vehicles for ground transportation, new large aircraft, high speed rail, megaships.

The paper ends with a few words on the possible implications of these technological developments for transportation planning and decision-making.

Some New Technologies Affecting Transportation

(1) Telecommunications and Information Technologies

Over the last two decades, telecommunications and information technologies have come to play a major role in the world economy as well as in the day-to-day lives of people around the globe. In transportation, these technologies have found diverse applications: speeding freight movements and increasing their reliability at every scale; international to local, helping motorists get directions or find alternate routes when their planned route is congested; providing transit riders with trustworthy information on when the next bus will arrive.

Cellular Phones and GPS Systems

One of the most ubiquitous telecommunications technologies is the mobile phone. Today's lightweight phones and near-ubiquitous networks (cellular or satellite) provide speedy and economical services, allowing users to communicate almost anywhere in the world. Ownership of mobile phones has greatly increased in the US over the past decade,

although it still is lower than in some other countries. In addition, some auto manufacturers have built phones into the car.

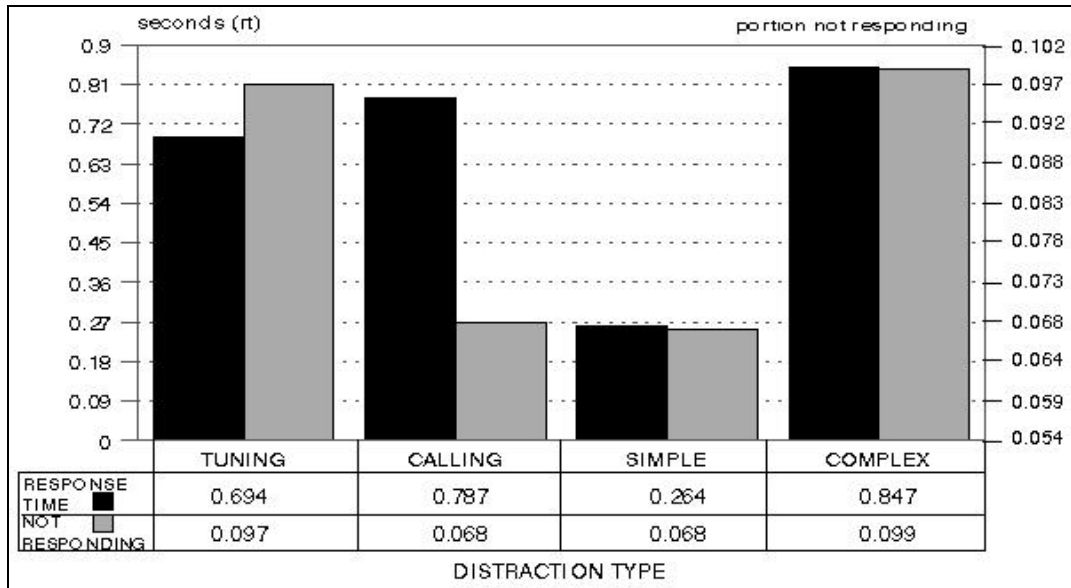
Special-purpose GPS systems also have been introduced as a travel aid, providing information on routes and travel times. Some of these systems are linked to real-time traveler information systems, so have current data on travel conditions. Some GPS systems also are linked to vehicle locators, offering the motorist a chance of recovering the vehicle in case of theft or getting directions based on the vehicle's location. The equipment is standard on a few cars and can be added to many others. . For example, General Motors (with the GM star) and Ford have already adopted a system that links a driver to a location system. At the same time, though, these functions are being added to cell phones and other hand-held devices, so that many more users may have the same functionality in a different format.

Today, those equipped with mobile phones and other advanced hand-held computers can conduct business, talk to friends, get maps and directions to nearby hotels and restaurants, and even send and receive email while on the go. These in-vehicle and portable communication devices may be taking some of the frustration out of congestion, since delays can be reported to employers, business associates, or friends, and time spent in the vehicle can be put to use.

Mobile phones are widely used as a safety /security device by motorists, who can call for help in case of an emergency, or report a roadway hazard or accident to authorities or to traffic reporters who then broadcast the information on the radio. There is some evidence that mobile phones are reducing demand (though not entirely eliminating it) for roadside call boxes. However, this mobile connectedness also has a downside. many 911 operators have found that drivers/ passengers dial 911 to ask for directions, learn about traffic conditions, and so forth. Such non-emergency calls delay the speed with which 911 operators can aid a victim who has a serious emergency.

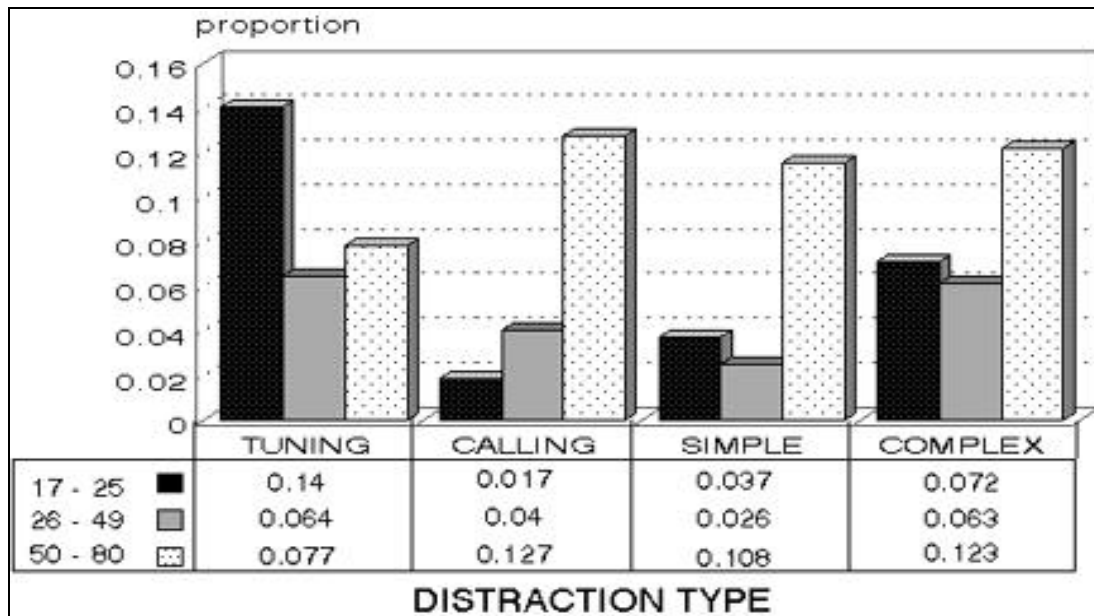
There also is some evidence that mobile phone use can cause driver distraction and increase accidents. About 25% of the 6.3 million crashes a year are due to distracted drivers. While cell phone usage is not the only source of distraction, it is a serious one: Figures 1 and 2 show how much cellular phones distract the driver's attention.

Figure 1) Increase in reaction time by distraction type



Source: AAA website <http://www.aafts.org/text/research/cell/cell0toc.htm>

Figure 2) Increase in reaction time by age and distraction type



Source: AAA website <http://www.aafts.org/text/research/cell/cell0toc.htm>

In response, some states and cities now require that devices allowing hands-free operations be used if the cell phone is to be utilized while the vehicle is in motion. Brooklyn, Ohio, and Marlboro Township, NJ were the first to ban the use of hand-held phones by a driver while the vehicle is in motion [t]. California, Florida and Massachusetts have laws limiting cell-phone use in moving vehicles, according to the National Conference of State Legislatures [w]. Advances to reduce the risk include converters that allow a cell phone to be mounted on a connector that plugs in to the car cigarette lighter and used with a headset, as well as mobile speaker phone options and voice-activated dialing and other commands. . Voice-activated phones are appearing on the market and are being introduced in the 2001 models of some types of cars.

Telesubstitutions

Advances in computer and communications technology such as telecommuting and e-commerce may mitigate the need for some transportation capacity improvements. Telecommuting, teleshopping, video conferencing, and other “telesubstitutions” may become significant factors shaping new transportation trends in the years to come. These trends will produce fundamental changes in social and economic activity.

Telecommunications and information technologies are not only opening up new options for travelers, but are also altering the options for living and working. One application of telecommunication technologies that has received considerable attention by transport experts is telecommuting. Working at home has always been technically possible for the many workers, if the job does not necessitate face-to-face contact with other workers or clients or the use of massive or prohibitively costly equipment. For many office workers, telecommuting has been an option since the invention of the telephone and the typewriter. However, it is the growing at-home availability of low cost, multiple line phone connections, personal computers, and email and web technologies that has made working at home a realistic possibility for many.

Still, fewer than five percent of the workforce actually chooses to work from home the majority of the time. The reasons for this are many and varied, and include management styles that reward workplace visibility, the high level of communication about work that occurs informally, desires for keeping work from spilling into home activities and vice versa, and personal household scheduling issues. Also, policies aiming to relax constraints on work-related schedules are not sufficient to shift commuters into off-peak travel because timing of the work trip depends on the timing of nonwork activities (Picado, 1999).

Working at home one or two days a week is also an option for many, however, and there does seem to be some increase in this activity. In addition, outside sales and service workers are increasingly starting and ending their days from home, traveling to the office or central facility only a few days a month.

Reductions in the number of individual work trips may encourage individuals to move away from their place of work, thus limiting their ability to use public transit or form a car pool. Household locations also may be changing due to the widespread availability of telecommunications and information technologies. Telecommunities – towns that are designed for advanced telecommunications systems – are cropping up at the fringes of metropolitan development in the US and Canada, offering state of the art telecommunications links as compensation for physical remoteness. Studies to understand the effects of such high levels of connectivity are just now underway. In addition, a number of existing communities (e.g., Blacksburg, Virginia) have connected every household to the Internet and to community services for electronic communications, vastly increasing the ability of local businesses and residents to use the internet for both routine and novel transactions.

Less dramatic but possibly of larger overall impact is the ability of telecommuting households to settle in rural locations remote from the place of work and trade a drastically long commute made once a week or a few days a month for working at home in a preferred location. Here, too, studies are just now underway to assess these choices and their impact.

While the impacts of telecommunication advances on household location are quite unclear, there is no doubt that business locations have been strongly affected by the ability to stay in touch electronically. Some companies have maintained downtown locations for executive, legal, and financial functions of their enterprise, but have moved units doing more routine office work and service functions such as data processing and accounting to less costly suburban locations. Other companies have found that the lower-cost suburban locations suffice for all of their functions. In both cases, ubiquitous telecommunications and information technology link the business functions and tie them to larger sources and markets, though adequate physical connections via surface transportation and major airports also are required.

As telecommunications and information technologies permeate households and businesses, other changes in activity and travel patterns may be emerging. Increased use of the Internet coupled with increased acceptance of electronic signatures and better security for electronic transactions may be cutting into paper transfers of documents. E-commerce, currently undergoing a sharp contraction after exuberant expansion in the last couple of years, may eventually reduce travel for shopping (though the evidence to date suggests that it may be a complement rather than a substitute). E-commerce also may increase delivery volumes and perhaps delivery traffic as well. These matters remain largely speculative, however, and are currently topics of research.

(2) Intelligent Transportation Systems (ITS)

The infusion of information technologies into transportation, commonly referred to as intelligent transportation systems (ITS) in the United States and “transport telematics” in Europe, is a global phenomenon. Information technologies applied to transportation include a broad array of devices, functions, and supporting tools used in sensing, generating, processing, transmitting, communicating, monitoring and presenting information. Examples include ramp metering, adaptive signal control, GPS navigation, Automated Vehicle Location, traveler information services, collision avoidance, and automatic fare/toll collections. Longer-term options include Automated Highway Systems and automated transit.

The implementation of intelligent transportation systems has been slower than proponents had initially expected, for complex and interrelated reasons: high R&D costs, the complexity of introducing new components and processes in complex systems, high implementation costs and risks of investment, slow institutional change, slow social acceptance. Nevertheless, several ITS technologies are finding their way into numerous applications. These include global positioning systems, traveler information services using cellular phones or Internet access, and smart cards. Other increasingly widespread applications of ITS technologies include traffic operations applications, such as ramp metering, bus application of Automatic Vehicle Location (AVL), advanced traffic signal systems, buses priority at traffic signals, Intelligent Vehicles (smart cars), and Automated Highway Systems (AHS).

Global Positioning Systems (GPS)

GPS is a satellite-based radio navigation system developed and operated by the U.S. Department of Defense. GPS has been applied in every transportation mode (even walking), but its main uses are for keeping track of vehicle identity and location, and serving as a navigational aid. GPS has already replaced most of the old navigational systems on ships and planes, and is increasingly being applied to provide updated real-time, location and navigation support for bus, rail and truck transportation. GPS is also being used in data collection and recording. For example, data on sidewalk conditions at specific locations can be recorded using GPS technologies, probe vehicles equipped with transmitters can be used to provide information on travel patterns. In recent experiments clip-on devices are being used to gather travel information from individuals. Currently the accuracy of GPS in civilian use is around 10 meters, though with “differential GPS”, a GPS system that uses a “known position” to account for error in position, accuracy can be improved to about 1 meter or less..

Automatic Vehicle Location (AVL)

Automatic Vehicle Location (AVL) is a technological capability to track vehicles and relay location information to central locations. . By knowing the exact location of the vehicles, the AVL technology allows better management of fleet operations and vehicle dispatch. A variety of technologies can be used:

- i. Dead reckoning – using odometers (devices which measure distance traveled by counting the wheel revolutions) and compasses
- ii. Beacon and either tag or radio - e.g. microwave, infra-red, inductive loops
- iii. Radio triangulation – e.g. loran-C, Omega, data-transmitter
- iv. Satellites – GPS (global positioning system)

Transit systems were early adopters of AVL. During the last two decades, AVL systems have come to be widely accepted and sought as key components—for improved operational management of bus fleets. The newer systems are combined with geographic information systems and wireless communications, and the more advanced systems also are linked with traveler information services to update transit riders about expected arrival times of buses. The continuing decrease in price of AVL hardware has led to AVL systems being an attractive and affordable proposition for most transit operators.

The relative ease of knowing vehicle location (both onboard and at a central dispatching center) may make feasible for transit and paratransit providers to make modest diversions from the standard route when pick-up or drop-off is requested, “on the fly”. Such services in the past had to be scheduled well in advance of the trip.

AVL also is widely used by emergency response vehicles such as ambulances, where knowing the exact location of the vehicle provides improved response time and, together with GPS and GIS capabilities, faster routings.

Smart Cards

Smart cards are equipped with silicon chips that receive and transmit data. In transportation applications, smart cards are being used for vehicle identification and as well as for touchless, automatic payment of tolls, fares, and fees. Several different types of cards are available, including varieties of contact cards and contactless cards. Contact cards require the user to insert his/her card into a reader that scans the card (often magnetically) and processes the transaction (signals the garage door to open, deducts the fare). Contactless cards use radio waves to conduct the same transactions.

Smart cards are increasingly favored in the transit industry because they reduce the need for handling money, with attendant expenses and losses. Contact cards have been used for many years in transit and parking applications and are becoming more sophisticated, with added applications. Contactless cards are a newer introduction. While in early

applications accuracy was limited to short distances between card and reader, the technology is rapidly improving. The contactless cards are increasingly preferred because they are faster for both the user and the operator, and require less maintenance than contact cards (contactless cards do not malfunction if people sit on their cards, bend it, etc.)

In addition, smart card technology makes it possible to implement more complex fare structures than are usually feasible with cash collections, for example permitting time of day pricing and discounts for particular user groups such as senior citizens, youth, and low income. For example, preprogrammed discounts for youth, senior citizens and long-term cardholders are already implemented in Seoul. Another potential advantage is that smart cards can offer a universal payment method for multiple systems. For example, Hong Kong’s “Creative Star” program uses smart cards to link the Mass Transit Railway, Kowloon Canton Railway, Kowloon Motor Bus, Citibus, and Hong Kong and Yaumati Ferry System.

The U.S. has been slow to apply smart card technology in comparison to its European and Asian counterparts. (See Table 1.) Furthermore California, though a leader in the development of advanced electronics, is just now beginning to apply smart card technology for transit fare and highway toll payments; in this application it is well behind the northeastern United States. Automated toll collection has been in place for a number of years on the New York State Thruway, for example, and touchless transit payment cards have been in use for several years on the New York and New Jersey transit systems.

Table 1) Smart Card Implemented Projects

Country	Project	Number of Cards
Brazil	Curitiba	1.5 million cards
China	Macao	100,000 cards
China	Hong Kong CreativeStar	4.6 million cards
Czech Republic	Czech Republic / Slovakia	100,000 cards
Finland	Approximately 20 transit fare card applications	500,000 cards
France	Valence, Department du Tarn, Forbach, Department du Merthe et Moselle	100,000 cards
Great Britain	Hertfordshire	30,000 cards
Korea	Pusan	1.8 million cards
Korea	Seoul	6 million cards
United Kingdom	London Transport	3 million cards expected

Security is another application of smart card technology. For example, Chicago’s O’Hare Airport uses smart cards to keep track of truck drivers. When truck drivers bring goods into the airport, their smart card is scanned to identify who the driver is and what s/he is

carrying into the airport. In case of an accident, the safety and inspection board airport can link the case back to the driver bringing the goods into the airport. Smart card applications also increase security in parking structures and elevators.

Future developments of Smart Cards are towards smart chips which could be attached to vehicles, driver licenses, ID cards, etc., as well as integrated cards that include multiple applications (credit / debit / bank teller cards, e.g.). Also, applications to commercial vehicle operations are an active area of research and development.

Travel Information Services

Traveler information services, provided by both public and commercial enterprises, enable individuals to make better use of the transportation system. Advanced Traveler Information Systems (ATIS), which provide information on both real-time and projected conditions, allow users to select the best modes, routes, and departure times before starting the trip and to make adjustments while already en route. Since the information should save time and reduce costs, benefits extend to delivery vehicles, taxis, and shared-ride services and their customers as well as to individual users. Some traveler information systems also provide amenities, for example, information on restaurants, hotels, and other services.

TravInfo in the nine-county San Francisco Bay Area and TravelTip in Orange County, CA are two examples of travel information services. These advanced systems are combining data from Advanced Public Transportation Systems (APTS) and Advanced Traffic Management Systems (ATMS) to improve the information provided to users. Internet-based services also are increasingly available, and today, anyone with Internet access can get virtually real-time data and even images of traffic on critical roadways.

Smart Cars /Intelligent Vehicles

Since its invention, the automobile has been the application for many innovative technologies. In recent years, new automated functions have appeared, such as antilock braking systems. Initially, these innovations have been relatively expensive, and thus found primarily in luxury cars. Over time, price reductions have allowed the innovations to extend through the vehicle fleet.

Computer hardware and software now permeates the modern automobile, controlling fuel use and emissions, managing electrical systems, monitoring engine and brake performance. The push for Smart Cars builds upon these elements and extends them, with a special focus on improving safety. The hope is that the new technologies, like their predecessors, will be introduced in a few cars first and then will diffuse through the fleet.

Some examples of smart car features now available or being actively pursued are following:

- In-vehicle navigation – using GPS and CD-ROM digital maps both onboard and at a central dispatching center to enable on-the-fly route adjustments
- Emergency service systems (Mayday Systems) - devices that sense an accident, or can be activated by the vehicle operator, and automatically communicate the situation (typically using satellite or cellular systems) to an emergency response agency.
- Vehicle suspension, control, and steering enhancement.
- Collision warnings - Devices based on radar or other sensors to alert drivers to situations in which collision is imminent.
- Operator inattention detection - to detect driver drowsiness, fatigue and other behaviors including inattention and warn the driver
- Vision enhancement - using radar or thermal imaging to enhance the operator's view, particularly in adverse weather and darkness, and to project an image on or near the windshield.
- On-board diagnostic systems (OBD) –to monitor the function of emissions control systems, control/regulate them, and notify the driver or a remote sensor
- Positive Train Control - to monitor train separation through the use of locomotive GPS position determination and onboard track geometry data, with digital communications to a control center.
- Traveler information – on-board databases, linked to additional data sources, for directions, information on nearby attractions, traffic conditions, etc.
- Entertainment and communications –adding a computing platform into motor vehicles to perform computing and communications tasks such as wireless telephone, fax, Internet access, speech recognition and synthesis for user interaction, public and private traveler information systems; multimedia entertainment applications for passengers; and user-customized driver information displays.

Safety is a special focus of many of the proposed Smart Car features. Table 2 shows how new technologies are expected to help reduce crashes and their severity.

Table 2) Cause of accidents and new technology

Type/ Cause of crash	Technology	Function
Rear end	Collision warning systems Adaptive Cruise Control	To reduce accident fatalities, injuries and property damage through object detection, collision warning and ultimately collision avoidance by accident prediction and automatic vehicle control.(braking , throttle adjustment , steering). To extend the conventional cruise control by enabling the driver to automatically follow a slower preceding vehicle
Lane change	lane warning systems	To monitor the lane change and relative speed of other vehicles beside the equipped car , and warn drivers of the potential for collision
Road departure collisions	Road departure collision warning systems	To warn the driver when the vehicle is likely to deviate from the lane of travel by tracking the lane or road edge and to suggest safe speeds for the road ahead <i>Future capabilities may integrate an adaptive cruise control function to adjust vehicle speed for the shape of the road, based on an input from a map database and navigation system.</i>
Intersection collision avoidance	Intersection collision avoidance systems	To monitor a vehicle's speed and position relative to the intersection along with the speed and position of other vehicles in the vicinity advising the driver of appropriate actions to avoid a right of way violation or impending collision. <i>This problem is complex and according to the IVI, " while this service will be implemented first through in- vehicle systems, it will be augmented with information from map databases and co-operative communication with the highway infrastructure.</i>
Reduced visibility	Night vision systems	In vehicle systems use infrared radiation from pedestrians, animals, and roadside features to give drivers an enhanced view of the road ahead. Night vision products are already being introduced in the market. <i>Future versions may include information from highway infrastructure improvements such as infrared reflective lane- edge markings.</i>
Driver fatigue	Driver condition warning systems	To alert drivers of conditions such as drowsiness, a problem area for which the DOT is currently developing a real time , on board monitor which measures the degree eyelids are covering the pupils , according to IVI , "the best known predictor for onset of sleep

Collision Warning Systems

Motor vehicle crashes are the leading cause of death for persons from 6 to 33 years old (NHTSA 1997 data). The economic cost alone of motor vehicle crashes in 1994 was more than \$150.5 billion. A major portion of these crashes result from driving task errors. Collision warning systems offer immense potential to reduce the number of vehicular crashes caused by driver errors. .

The purpose of collision warning systems is to reduce accident fatalities, injuries and property damage by applying technologies that provide object detection, collision warning and eventually, collision avoidance by accident prediction and automatic vehicle control (braking, throttle adjustment, steering).

Collision warning systems are currently undergoing active research and development, and significant advances are anticipated for the next decade, both lowering costs and reducing the currently problematic rate of false alarms.. However, applications are already fairly common. Some automobiles, for example, have simple warning systems that engage when the car is backing up. Also, a number of trucking and freight companies in the US are already using collision warning systems; the cost of \$2000 per unit is covered by substantial reduction in accidents (especially valued by an industry that is largely self-insured.).

Related technologies both improve safety and increase comfort. Fir example, Adaptive Cruise Control offers tremendous potential to relieve driving stress and make driving enjoyable and safer. ACC is already being offered in some vehicles in Europe and Japan. It is expected to be introduced in the US within the next two years. Also, systems to aid drivers in conditions of reduced visibility are being introduced (e.g., the Nightvision system is available on the Cadillac DeVille.)

Commercial Vehicle Operations (CVO)

Advanced technologies and information networks are expected to increase productivity and efficiency for both commercial fleet operators and state and federal motor carrier regulators. The potential for cost savings and efficiencies is tremendous. CVO services generally focus on freight management, commercial vehicle electronic clearance, automated road side safety inspection, on-board safety monitoring, administrative process, hazardous materials incidents response, and. international border crossing applications. CVO systems should both speed up processing and reduce errors in freight management, permitting paperless exchange of invoices, customs documents, bills of lading, and other materials. This should significantly reduce delays, a major element in overall commercial vehicle costs. Together with the fleet management and operations systems described earlier, these CVO applications of new technologies are transforming commercial vehicle business.

Automated Highway Systems (AHS)

The AHS program is the fully automated control of vehicles operating on dedicated lanes in high priority traffic corridors. In theory, AHS could substantially improve the safety and mobility performance of highways. . For example, AHS offers the potential for substantial improvements in throughput (both peak and average), safety, trip predictability, level of service, inclement weather operation, mobility and air quality.

AHS focus on the potential benefits and feasibility of a smart vehicle that can communicate with a smart infrastructure. Because the AHS will share many subsystems with collision avoidance systems—such as vehicle-based sensors, computational elements, and the driver interface, the two research programs are closely coordinated. Automated vehicle control refers to a set of lateral (steering), longitudinal (speed and headway), and overall system control elements which will be combined into an Automated Highway System (AHS).

Initial deployment and operation of AHS is expected to focus on high priority routes located in high demand, major urban and inter-city freeway corridors. A prototype AHS was tested in I- 15 Reversible Express Lane, San Diego, CA. The test was successful, however, the problems such as the design of roadway (especially entrance and exit), the design and production of AHS-related maintenance and construction equipment are currently studied.

Advanced Air Traffic Control

Significant improvements in air traffic control (ATC) are widely considered to be critical in the handling of growth in the demand for air travel and air freight. Advanced air traffic control systems would allow airports to increase the number of aircraft that can be handled and also should reduce delays caused by weather. As with larger aircraft, however, the effects of adding capacity to the ATC system will reverberate throughout the airport, airside and landside, and will also have significant effects on ground transport systems. In addition, the environmental impacts of increased air traffic, particularly the noise effects, will require attention.

At the same time, plans and systems are currently being developed for transition to a conceptually new approach—free flight—in which aircraft location is determined onboard by augmented GPS technology, rather than by ground radar facilities, with greatly increased flexibility given to crews in choosing routes. Such applications would relieve some of the pressure on the ATC system. Selected core capabilities of Free Flight Phase 1 (FFP1) will be partly deployed by 2002.

Currently about 70 percent of corporate and over half of business-use aircraft have GPS devices as navigational aids; about 40 percent of personal- use aircraft have them. More advanced GPS systems are rapidly being deployed, For example, GPS systems designed

to avoid collisions into terrain are now being installed by U.S. airlines. Traffic Alert and Collision Avoidance System technology provides pilots with alerts of other aircraft potentially on a collision course.

GPS is also being applied to identify, track, and control aircraft and vehicles on an airport surface to an accuracy of 1 to 3 meters., allowing a reduction in terminal separation standards including bad weather condition standards. With the GPS application Oceanic Navigation, precision navigation will be available to aircraft out of range of land-based systems. Automatic dependent surveillance (ADS), based on reporting of GPS-derived position by satellite or high frequency data link, will provide the oceanic controller with a radar-like display of aircraft position. Over time, oceanic operations will evolve to resemble those over land, with much reduced separations and the flexibility associated with operating in a surveillance-based air traffic control (ATC) environment.

(3) New Systems

Alternative Fuels and Vehicles for Ground Transportation

Alternative fuels were in widespread use in the automobiles of the early years of the century, as vehicle manufacturers experimented with different vehicle designs and power systems. Alternative fuels received attention again during World War II, when import supplies of petroleum were disrupted and domestic production was directed toward the war effort. More recent interest in alternative fuels stems from the energy crises of the 1970s and early 80s, and from concerns about the environmental damage done by the burning of fossil fuels. A decline in interest occurred during the late 1980s and 1990s, when energy prices were low and fuel supplies had expanded, and during this period most gains in energy efficiency were used to power bigger, more heavily equipped vehicles. However, recent price jumps, together with continued difficulty in attaining air quality standards and growing concerns about global warming, have again given a boost to research on alternative fuels and vehicles that can effectively use them.

Currently, a variety of alternative fuels are being used, and even more are the subject of active research. Among the in-use fuels are reformulated fuels designed to reduce emissions (“clean gasoline”), as well as alcohol fuels (ethanol, methanol) and mixes, natural gas (methane, CNG/LNG), and electric power (batteries, fuel cells, hybrid electric-gasoline.). However, significant problems are apparent with many of the options. Some have poor pollutant emissions characteristics, and several are poor performers from a greenhouse gas perspective. Some, because of limited availability, problems in handling, or limitations on range, are best used in specific market niches (e.g., service vehicles, buses, passenger vehicle fleets) rather than in mass markets. High up-front or life-cycle costs are also barriers to more widespread use of alternative vehicles and fuels.

The alternative fuels currently being tested include:

- Liquefied petroleum gas (LPG): a fossil fuel derivative composed of 95% propane and 5% butanes. It produces lower CO emissions but NO_x emissions may be higher.

- Natural gas: a fuel in compressed (CNG) or liquefied (LNG) form. The CNG form, more common in the transportation sector, is stored in high-pressure cylinders. CNG generates lower CO and VOC emissions than conventional gasoline.
- Methanol : wood alcohol made form natural gas, coal or biomass
- Ethanol: Grain alcohol made form corn, sugarcane or woody biomass. Ethanol blends may reduce CO emissions but their effect on ozone is negligible.
- Electricity: Electric vehicles may be powered by batteries charged at home or at charging station with electricity form power pants. They have no tailpipe emissions; overall emissions depends on power plant energy sources.
- Hydrogen: a clean-burning fuel that can be produced from coal, natural gas, oil, solar, or wind energy. A vehicle operating on a fuel cell, which generates electricity by harnessing the reaction of hydrogen and oxygen to make water produce no CO or VOC emissions and extremely low NOx emissions.

The following table shows advantages and disadvantages of these alternative fuels.

Table 3) Pro and Cons of Alternative Fuels

Fuel	Advantages	Disadvantages
Electricity	<ul style="list-style-type: none"> • Potential for zero vehicle emissions • Power plant emission easier to control • Can recharge at night when power demand is low 	<ul style="list-style-type: none"> • Current technology is limited • Higher vehicle cost, lower vehicle range, performance • Less convenient refueling
Ethanol	<ul style="list-style-type: none"> • Excellent automobile fuel • Very low emission of ozone-forming hydrocarbons and toxics • Made from renewable sources • Can be domestically produced 	<ul style="list-style-type: none"> • High fuel cost • Somewhat lower vehicle range
Methanol	<ul style="list-style-type: none"> • Excellent automobile fuel • Very low emission of ozone-forming hydrocarbons and toxics • Can be made form a variety of feedstocks including renewable 	<ul style="list-style-type: none"> • Fuel could initially be imported • Somewhat lower vehicle range
Natural gas (Methane)	<ul style="list-style-type: none"> • Very low emission of ozone-forming hydrocarbons, toxics and carbon monoxide • Can be made from a variety of feedstocks including renewable • Excellent fuel, especially for fleet vehicles 	<ul style="list-style-type: none"> • Higher vehicle cost • Lower vehicle range • Less convenient refueling

Propane	<ul style="list-style-type: none"> • Cheaper than gasoline today • Most widely available clean fuel today • Somewhat lower emission of ozone-forming hydrocarbons and toxics • Excellent fuel, especially for fleet vehicles 	<ul style="list-style-type: none"> • Cost will rise with demand • Limited supply • No energy security or trade balance benefit
Reformulated gasoline	<ul style="list-style-type: none"> • Can be used in all cars without changing vehicles or fuel distribution system • Somewhat lower emission of ozone-forming hydrocarbons, nitrogen oxides, and toxic 	<ul style="list-style-type: none"> • Somewhat higher fuel cost • Few energy security or trade balance benefit

Source: EPA Website <http://www.epa.gov/oms/06-clean.htm>

Ongoing research aims to improve fuel characteristics and performance as well as to design vehicles that can effectively use the altfuels (e.g., “city cars”.) Work also is continuing on the design of effective networks or mechanisms for refueling and service, and on technical and institutional ways to reduce costs. In addition, researchers are looking into still more alternative fuels, ranging from biodiesel to hydrogen powered fuel cells to solar energy.

Among alternative vehicles, hybrid electric vehicles, also known as HEVs, are currently being sold by major manufacturers. The HEVs combine an internal combustion engine with the battery and an electric motor of an electric vehicle. Electric operation is used for short trips at low speeds, gasoline for higher speeds and longer distances. In such applications, HEVs are much more environmentally friendly than the average motor vehicle, providing twice the fuel economy of a comparable conventional car. At the same time, the internal combustion engine provides the range and power performance of a conventional vehicle when such range and performance are needed, overcoming the performance limitations of EVs. While their advantages are considerable, HEVs also have some serious disadvantages. For example, currently, HEVs are extremely costly to produce, and therefore expensive to buy. In addition, maintenance costs are high both because few repair shops are trained and equipped to handle these technologies, and because specialized parts are extremely expensive. Altfuel availability and cost may be another consideration, depending on the fuel and the application. Some of the fuels, such as methanol, pose health and safety issues.

From a policy perspective, which alt-fuel or alt-vehicle is “best” depends on the specific objective being considered- reducing pollutant emissions, cutting greenhouse gas emissions, lowering toxic exposures, reducing noise, or reducing consumption of nonrenewable resources. Their introduction could be aided by policies and incentives favorable to the introduction and use of alternative fuels and vehicles. Such policies and incentives could range from government purchase of alternative vehicles and fuels for its own use, to tax incentives to encourage their purchase and use. Development of appropriate policy instruments will require considerable effort.

Alternatively, if markets for alternatives emerge on their own; their policy implications could be significant. In particular, revenues from gasoline and diesel fuel taxes could be affected by shifts to alternative fuels and vehicles, and a host of new environmental, safety, and mobility issues could arise. Regardless of the implementation pathway, then, if large-scale introduction of any alternative fuels and vehicles does occur over the next several decades, the impacts on transportation planning could be significant.

New Large Aircraft (NLA)

“New large aircraft” (NLA) refers to any future aircraft larger than the Boeing 747-400. Since the middle of 1990s, two major aircraft manufactures, Airbus and Boeing, has been developing new large aircraft (NLA), also known as VLCT, (Very Large Commercial Transport), VLTA (Very Large Transport Aircraft), and VLA (Very large Aircraft). It has been regarded as a potential way to accommodate the significant air travel growth. Airbus plans to introduce a so-called Stage One NLA (500 or more seats) in 2001-2002, while Boeing stopped its NLA development.

NLA are being considered as a potential way to accommodate the significant growth that is forecast for both domestic and international air travel. However, the introduction of NLA would have a significant impact on not only on airports (both airside and landside), but by allowing a near-doubling of passengers per flight, will also have potentially large impacts on the ground transportation systems that provide airport access. On the airside, both the NLA’s wide wingspan and long fuselage will create the need to increase the size of runways, taxiways, apron and gate positions. On the landside, the high passenger capacity will require larger passenger processing facilities. However, the policy development concerning the NLA is still in the beginning stage.

In 1997, Boeing decided not to launch NLA development due to cost versus price issues and limited market while the Airbus continued to develop and marketing for 500+ seaters. Currently, Boeing is working on aircraft that are close to previous models, but targeting them to compete with the proposed NLA A3XX-100 super jumbo transport of Airbus. If and when such aircraft are introduced in significant numbers, their impacts will be felt not only in the market for aircraft but also in the broader air transport system.

High Speed Rail

High speed rail (or more broadly, high speed ground transportation, to account for technologies such as maglev) are systems with trains or other ground transport vehicles traveling at speeds at or above 200 km/h. The United States lags behind other countries in the application of this these technologies; France, Germany, and Japan, and to a lesser extent Great Britain and Sweden, have been leaders. There are, however, a number of states in which high speed rail or related technologies have been under serious consideration, including Florida, Texas, and California.

Table 4) Proposed major U.S. high-speed rail corridors

Corridor	Approximate Route length (km)	Technology	Estimated Cost
Orlando Airport – International Driver	22 km	Maglev	\$5 million
Tampa-Orlando –Miami	840 km	High-speed rail	\$6.8 billion
Houston – Dallas- Austin – San Antonio	1000 km	High Speed rail	\$5 billion
Anaheim – Las Vegas	425 km	Maglev	\$5.1 billion
Pittsburgh – Airport – outlying communities	30 km	Maglev	Estimate unknown

High speed rail has been proposed as an alternative to both long distance automobile travel and short-haul air travel. Access, and hence network topography and terminal location, is key to the competitiveness of this mode of transport. High speed rail would be considerably faster than auto travel times only if access and from the stations is not too long and if stops are few and/or of short duration. Similarly, for travelers with convenient access to or from a high speed rail terminal, total door-to-door travel time could be as fast or faster than for air travel, where access times and terminal delays are often high.

Maglev can be thought of as a high speed train without the rails.. Magnetic levitation generally employs magnetic forces for non-contact suspension, guidance, and propulsion from 2 superspeed Maglev systems: German Transrapid and Japanese Linear express. The Maglev trains are expected to increase a train’s speed to 400 – 500 km/h. As for the Maglev systems, the German Transrapid and the Japanese Linear express both use different types of techniques to enable a train to run close to the tracks without touching the rails. The German Transrapid uses Electromagnetic suspension (EMS) which takes advantage of the attractive force between the vehicle-borne electromagnets and the ferromagnetic guideway components. The Japanese Linear Express, on the other hand, uses electrodynamic suspensions (EDS). The EDS utilizes the force created by superconductive magnets that will carry the vehicle close to the track. With a Maglev system in place, predictions of much faster, speedier train can be anticipated. Maglev systems will become a prime HSGT tool for the future.

HSGT provides many advantages, mostly concerning the shorter travel times. However, it faces a number of barriers including costs, concerns about safety, concerns about environmental impact, and in some cases community impacts as well. First, high speed rails are costly. For example, the Florida Overland Express (FOX), anticipating completion in 2010, is estimated at \$4.8 billion. For most HSGTs to be maintained, these high speed trains need to have 2 million to 17 million riders per year.

Also, safety has been a concern. Rail tracks must always be clear of danger before HSGTs are allowed to proceed on their course. This requires vigilance at keeping the

right of way clear and makes it likely that the HSR will have significant severance effects on habitat. In addition, HSGT technologies lead to questions of the role of the driver and the role of the computer. The new technology installed in trains can ultimately require the minimum use of the driver, as the train can be placed in complete automatic function. However, many contend that drivers are necessary and computer displays should only act as an aid to the person in charge.

Megaships

In the 1990s, the rapid increase in the volume of water shipping led to vessels being upsized considerably. These large container ships, sometimes referred to as mega-ships or super ships, are usually 4,500 TEU or larger and require 43-47 feet of water. As of November 1996, the world fleet included 36 containerships exceeding 4,500 TEUs, and another 45 post- were on order. Together these 81 vessels will account for 7 percent of the world fleet's container-carrying capacity, and most analysts expect the trend toward larger intermodal ships to continue. Approximately 40 percent of the new capacity on order is containerships in the 4,500 TEU+ megaship category. And many expect that there will soon be a vessel of 15,000 TEU, 400 m in length, 69 m beam, and 14m x 70m from trunk to keel.

Megaships' main advantage is their huge capacity. However, megaships can only be accommodated in large ports and sometimes requires investments (dredging, terminal development, ground access improvements.) even there. Ports play a primary role in sustaining many cities' economy. The U.S. military also is involved with ports through the military sealife command, including the US customs, and Coast Guard. The demand for ports to maintain economic success is by no means small, as ports are constantly competing against each other for business. Therefore, to understand the changing technology of megaships, it is also necessary to understand the type of port competition that exists today. There are six main types of activities that influence a port's economy. They are: port tradition and organization (i.e. local employment), port accessibility from land and sea, state aids, port productivity, port selection preferences of carriers and ships, and comparative locational advantages.

North American ports have experienced a changing revolution in the 1990s. Both ports of New York and Los Angeles have been huge areas of economic developing. However, both centers have also experienced the loss of income due to 'minibridge' and microbridge' traffic. In California, the San Francisco & Oakland ports are almost equal in development and economy. Both ports have been pressured from ports up north and south that offer loading and unloading capabilities. However, for both SF & Oakland, there has been a large local traffic from nearby that has sustained the economy of these ports. For San Francisco and Oakland to maintain their competitiveness, these ports should expect to be able to accommodate the future of megaships. Smaller ports that cannot accommodate megaships in turn become less competitive with the ports that can do so.

This is not necessarily the last word on the issue, however, recently, medium-size ports such as Seattle and Portland have gained market share despite their inability to handle megaships. Their continued competitiveness is due at least in part to their investments in landside information technologies that speed goods processing and intermodal transfers, and to the ports' good access to both highways and rail services, with relatively low congestion. Investments in intermodal linkages, logistics and operations thus are key elements in port competition.

Conclusions: Implications for Transportation Planners

Transportation technologies of the sort discussed here, and many more, are advancing every day. Planners need to be aware of coming technological changes so that they can integrate them or account for them in their planning and programs. Planners also need to be aware of a broader, more speculative set of technological possibilities and their implications so that they will not be caught by surprise by changes that might have been anticipated. Planning styles that utilize scenario development and testing with the participation of a wide variety of experts and interests are one way to manage the uncertainties raised by possible technological change. Monitoring also takes on added importance in such circumstances.

Planners also may be called upon to deal with issues that slow the development and implementation of desirable new technologies. Topics that planners may be called upon to address could range from institutional redesign, the forging of partnerships with other agencies and interests, and the development of experimental programs and their evaluation, to the development of new methods of finance.

As in other applications, new technologies for transportation offer the possibility of "better, cheaper, faster" transportation services. Planners will be called upon to evaluate new technologies along economic, social and environmental dimensions and to help decision-makers assess the opportunities and tradeoffs involved in the technological choices they make.

Economic impacts such as travel time and cost for passengers and freight will be affected by the choices of technology made over the next 20 years. These impacts are felt directly by travelers and shippers, but also reverberate through the economy, affecting competitive position in regional, national, and global economies. Assessing the economic impacts of new technologies versus existing ones will require not only forecasting and analysis but also some experimentation and evaluation.

In addition, planners will be expected to be able to consider alternative modes and the tradeoffs among them, as well as their interdependencies. Technological change in the aviation and water shipping industries is already having impacts not only on ports and airports, but on ground transport as well; technological possibilities in both air and surface transportation modes will need to be considered in making major investment decisions.

Environmental impact is a major motivation for many of the new transportation technologies being considered today, and positive environmental impact may well be the decisive factor in decisions about which new technologies will succeed. As experience with alternative fuels and vehicles has recently illustrated, new technologies that improve some aspects of transportation systems performance but harm others are likely to be rejected. Hence, planners will be called upon to thoroughly evaluate the options using multiple measures of performance.

Transportation's role in everyday life means that changes in transportation technologies will also have social impact. Past changes in transportation technologies have altered the patterns and locations of home and work, altered the use of leisure time, and affected public health. They have benefited many but left some behind. Future technologies are likely to do no less.

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