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NEEDS, CONCEPTS, AND ISSUES

Reviewed in this chapter are the nation's major highway safety and capacity needs that underlie efforts to develop and deploy fully automated highway systems. A general description of several automation concepts, ranging from partially to fully automated systems, follows. The chapter concludes with a brief discussion of some of the safety, institutional, environmental, and other public policy issues that arise in considerations of the prospects for deploying fully automated highway systems. Specification of a fully automated highway system will require understanding and balancing of these issues.

HIGHWAY SAFETY AND CAPACITY NEEDS

The need to reduce the incidence and severity of highway crashes, especially the large share caused by driver error, offers a compelling reason for investigating automated and other intelligent vehicle and highway technologies. Another is the need to accommodate escalating traffic on urban commuter routes and intercity passenger and freight corridors. Indeed, meeting these related needs through integration and improvements in motor vehicle and highway technologies is the central goal of the large federal research and development effort under way in intelligent transportation systems (ITS) generally (ITS America 1992, 1-1 to 1-2).

Safety

Impressive gains have been made in motor vehicle safety in the United States during the past three decades. In 1970, about 45,000 people were killed on the nation's roadways (excluding pedestrians). About 20 percent fewer fatalities were reported in 1996, although the number of miles traveled by the vehicle fleet rose more than 75 percent during that period (NHTSA 1996, Table 2; NHTSA 1997a, 23–28).

Among the reasons for this dramatic improvement are the introduction and use of occupant protection devices and features in motor vehicles, improved highway designs, and changes in certain driver behaviors (such as drunk driving). The highway and motor vehicle industries, the federal government, and state and local transportation and law enforcement agencies have all contributed to this progress, as have changes in public perceptions and expectations regarding motor vehicle safety and acceptable driving behaviors.

These gains notwithstanding, motor vehicle crashes remain a leading cause of accidental death and disabling injuries in the United States, especially among young people. The federal government estimates that in addition to lives lost and injuries suffered in the most serious crashes, traffic accidents of all kinds burden society with more than $150 billion in economic losses from property damage, traffic delays, lost worker productivity, fuel use, and other direct and indirect effects (NHTSA 1996). Although the current traffic fatality rate of 1 per 100 million km (1.7 per 100 million mi) is a historic low—and among the lowest in the world—further efforts to increase highway safety are warranted.

The factors contributing to highway crashes, especially those resulting in death and severe injuries, have been the subject of considerable research—as well as public programs and policies designed to address them. Automobile manufacturers and their suppliers have spent many years and billions of dollars researching, developing, and deploying motor vehicle safety improvements. State and local governments have sought to improve the safety of the roads on which these vehicles travel, including the performance of drivers. Within the federal government, the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration (FHWA) have the main responsibility for ensuring motor vehicle, highway, and driver safety.

One way that researchers frame the highway safety problem is to separate motor vehicle crashes into their pre- and post-crash phases. “Crash avoidance” is the term often used to describe improvements in vehicles, highway environments, and driver performance that can reduce the probability that a crash will occur. “Crash protection” and “crashworthiness” are terms that refer to improvements in vehicles and the highway environment that can reduce the severity of crashes—for instance, by protecting the vehicle’s occupants and reducing the impact forces of the collision.

Enhancements in crashworthiness and other measures to protect vehicle occupants in crashes have been the subject of highway and motor vehicle safety programs. FHWA and state and local highway agencies have sought to reduce crash severity by providing a more forgiving road environment—for example, through deflective guide rails, breakaway supports for lights and signs, crash cushions, wider medians, and tree-clear zones beside freeways. FHWA has fostered these improvements through its own research programs and by working with state and local authorities to encourage and mandate the use of safer roadway designs and equipment.

Likewise, motor vehicles have become more protective of occupants as a result of many changes in vehicle design, materials, and safety features. All new passenger cars, for instance, have energy-absorbing frames and bodies, seat belts, padded steering wheels, and air bag restraint systems. NHTSA has sought to increase vehicle crashworthiness through performance standards that encourage industry to develop safer vehicle designs and features. It also has promoted vehicle safety through other means. During the 1970s, for instance, the agency worked with domestic and foreign automobile manufacturers to establish an Experimental Vehicles Safety Research Program (later renamed the Research Safety Vehicle Program), through which occupant-protection concepts such as air bags, automatic seat belts, and other occupant restraints were demonstrated to industry and the public (TRB 1991, 146–147).

Improvements in crash avoidance have proved far more difficult to attain, largely because the probability of a crash is affected by an array of complex and interacting factors involving the drivers, vehicles, and the highway environment. The human factor—the driver—is particularly important. Driver error and poor performance, caused by factors ranging from momentary distractions to alcohol impairment, are the main contributory causes of most highway crashes. To compensate for or enhance driver performance, NHTSA and automobile manufacturers have focused much of their attention on designing vehicles that are easier to use and more responsive to drivers—for instance, through better braking, steering, stability, and visibility. Antilock braking systems, rear window defoggers, brighter head lamps, and high, center-mounted brake lights are examples of vehicle equipment designed to aid drivers in routine and hazardous situations. In addition, many improvements have been made in roadway designs, materials, and equipment to facilitate safe driving: flatter grades, left-turn lanes, pavements that drain well and are skid-resistant, rumble strips on shoulders (to alert drowsy drivers), and reflective signs and edge markings. To influence driver behavior directly, governments at all jurisdictional levels have sought to discourage certain hazardous driving habits, such as speeding and driving when drunk or fatigued.

Despite the many crash avoidance measures that have been undertaken, driver error remains the most important cause of motor vehicle crashes. In the belief that there is a large untapped potential for reducing motor vehicle crashes by improving driving performance, NHTSA has been developing new research tools to understand driving behavior, such as an advanced driving simulator. It also has evaluated crash data to better understand collision problem areas and their causal factors. Working with motor vehicle manufacturers and suppliers, NHTSA has begun operational tests to examine the potential for advanced vehicle systems that could detect impending crashes, alert drivers, and take temporary control of a vehicle if warranted (for instance, by applying the brakes in an emergency) (NHTSA 1997b, 1).

Full automation of highways and vehicles—that is, automation of routine driving tasks—has received comparatively little attention within NHTSA and the motor vehicle safety community generally. This lack of attention derives in part from the tendency for fully automated highways to be viewed as remedies mainly for congestion on urban freeways and main commuter routes (NHTSA 1997b, 3). Highway crashes occur throughout the vast public road system, and rural routes—seldom considered early candidates for full automation—are the location of a disproportionately high share of fatal crashes. Although nearly 15 percent of the nation's motor vehicle travel occurs on urban Interstate highways, they account for only 5 percent of fatal crashes (FHWA 1996, Table VM-2; NHTSA 1996, 1997a). Full automation of these urban freeways therefore is viewed as having a relatively limited impact on the overall highway safety problem in the United States. If fully automated systems could be applied to a wider assortment of driving environments—or divert significant amounts of traffic from less-safe roads—interest in them within the highway safety community could be expected to grow.

Highway System Capacity

During the past half century, the United States has experienced extraordinary growth in motor vehicle travel. Since 1950—a period in which the U.S. population rose by 75 percent—vehicle miles traveled nationally have grown nearly fivefold, doubling about every 20 years (TRB 1997, 40). In the past two decades alone, motor vehicle travel has grown more than two-thirds. Although much of this growth in driving has occurred on urban commuter routes, significant increases in travel have occurred on nearly all segments of the system, for all kinds of vehicles. DOT expects motor vehicle travel to grow another 35 to 50 percent over the next two decades (DOT 1995, 162–168). In the meantime (if recent history is an indication), the capacity of the nation's highway system will continue to grow—but at a pace slower than the growth in travel. Growing congestion is a likely outcome on many highways in fast-growing metropolitan areas.

Escalating motor vehicle travel has been caused by and has contributed to several important social and demographic trends, such as the maturing of the large baby boom population and the influx of women into the workforce and driver pool beginning in the mid-1960s. A decade earlier, the United States had embarked on the Interstate Highway System, a public works program that has added more than 72 000 km (45,000 mi) of modern freeways across the country. During this period, the country has become increasingly urbanized as metropolitan areas have grown in number and population. Metropolitan areas also are spreading out; nearly 20 percent of the land in the contiguous United States is located in areas defined by the Bureau of the Census as having urban population densities. By comparison, only 7 percent of the U.S. land area was classified as urban in 1950 (Bureau of the Census 1995, Table 40).

As metropolitan areas have proliferated and expanded, driving patterns have changed. In many metropolitan areas, the central city no longer accounts for the dominant share of the population or the largest number of jobs, shops, and other destinations. Traditional radial road and transit commuter corridors that carry residents and workers between suburban and downtown areas have become insufficient in many places as travel origins and destinations have become increasingly dispersed, varied, and distant. As a result, state and local transportation agencies have had to add capacity across their entire networks by building new roads such as beltways and bypasses and by widening and upgrading many existing routes that once served only local traffic. In the past decade alone, the amount of lane-mileage on the nation's urban arterials and collector roads has grown 20 percent (FHWA 1986, 1996, Table HM-60).

Road building, however, is expensive, time-consuming, and often controversial because of concern about traffic and environmental impacts, historic preservation, and protecting the character of communities. From 1990 to 1994, the average cost of constructing one mile of new federal-aid highway (consisting of primary and major secondary routes) was $1.75 million per km ($2.8 million per mi) (FHWA 1994, IV-36 and IV-37), not including the purchase of expensive rights-of-way. Road widening and other improvement projects averaged more than $600,000 per km ($1 million per mi). For most large urban areas, where the reconfiguration of a single interchange on a major freeway can cost tens of millions of dollars and cause substantial traffic disruptions, these figures would run much higher.

Faced with high costs and other difficulties associated with adding new travel lanes—including the need to control air pollution—many state and local governments are seeking ways to accommodate burgeoning traffic without creating more physical infrastructure. Many areas are trying to extract more capacity from their existing road networks through ramp metering, synchronized traffic lights, reversible lanes, travel on shoulders, better incident management, and other modifications to traffic operations. Some localities are trying to reduce travel demand by promoting transit, ridesharing, and more flexible work and commuting schedules. These efforts may have enabled some jurisdictions to defer large road-building projects or avoid more stringent actions to curb driving demand.

Interest in new ways to increase road capacity and influence demand for motor vehicle travel has sharpened as traffic congestion has worsened and continued to spread. Exactly how motor vehicle travel patterns and trends will unfold over the next several decades remains unclear. Some areas of the United States that today have excess highway capacity and few congestion problems may become more appealing to businesses and residents over time, providing a possible check on chronic and worsening gridlock in already congested urban areas. According to emerging demographic trends, a slowdown in the rate of growth in motor vehicle travel is likely during the second quarter of the next century, when a plateau may occur in the travel-intensive middle-aged population, now composed of baby boomers (TRB 1997, 56–61).

Even a somewhat slower rate of growth in motor vehicle travel, however, will continue to produce higher traffic volumes. About one-quarter of urban Interstates now carry more than 100,000 vehicles per day, and many carry much higher volumes. This figure represents a 15 percent increase over 1985 volumes, although the physical capacity (lane-mileage) of urban Interstates has barely changed during the period (FHWA 1986, 1996, Table HM-37). Traffic volumes would be even higher in many cases, except that highways have reached their capacity. Indeed, traffic volumes on more than 45 percent of urban Interstates are now above design capacity (the point where throughput and travel efficiency are maximized), compared with 35 percent in 1985 (FHWA 1986, 1996, Table HM-61).

Another cause for the sustained and rapid pace of growth in motor vehicle travel has been the growth in intercity travel by commercial trucks. Travel by tractor-trailers and other combination trucks has nearly tripled since 1970—making trucking by far the fastest-growing component of motor vehicle travel (FHWA 1970, 1996, Table VM-1). Not only has the Interstate Highway System become the primary means of personal travel for short- to medium-distance trips, it also has become the predominant means of transport for many kinds of freight. Combination trucks account for only about 6 percent of total vehicle miles traveled, but they are prevalent on Interstate highways (FHWA 1996, Table VM-1). On rural Interstates, which serve as main trunk corridors for intercity truck travel, combination trucks account for more than 15 percent of vehicular traffic (FHWA 1996, Table VM-1). Further growth in truck travel is expected, raising concerns about the ability of some heavily traveled intercity corridors to continue accommodating both freight and passenger vehicles safely and efficiently.

Confronted with the strong probability of continued growth in motor vehicle travel and the reality of an aging and slow-growing road network, some state and local governments are counting on ITS to improve traffic operations and overall system efficiency and capacity.

Intelligent transportation systems already are being deployed and tested throughout the United States. For instance, systems that collect and transmit real-time information on traffic conditions for travelers and transportation agencies—enabling the former to modify their travel plans and the latter to clear incidents and reroute traffic efficiently—already are in place. Transit authorities and trucking companies are using automated tracking and dispatch systems to dynamically route and reroute vehicles in response to information on traffic patterns and congestion. Navigation systems with enhanced pathfinding, or route guidance, are being used in selected areas and in test markets to give travelers more information on congestion and alternative routes. Electronic toll and traffic management systems that scan or communicate with vehicles to collect tolls automatically—such as the E-Z Pass system in the Northeast—are being deployed widely to reduce delays at toll plazas. Such systems eventually may be employed for variable toll pricing and other forms of travel demand management.

These and other ITS technologies and products have been grouped by the ITS community into five functional areas: advanced traffic management systems, advanced traveler information systems, commercial vehicle operations, advanced public transportation systems, and advanced vehicle control systems. As the technologies and systems in all of these functional areas are developed and integrated over time, they hold the potential to continually improve traffic operations and highway capacity. Indeed, over the longer term, ITS promises increasingly interconnected and compatible components that merge to form an "intelligent infrastructure."

A main promise of fully automated highway systems is dramatic gains in highway throughput. The ITS America strategic plan, for example, anticipates doubled or tripled traffic throughput in corridors supported by fully functioning ITS that include vehicle automation (ITS America 1992, I-12).

FEATURES AND CONCEPTS

ITS encompasses several advanced driving features and concepts, ranging from obstacle detection and warning systems that are possible precursors of partially automated driving systems to fully automated vehicles traveling on instrumented highways. Some automation features already are in use or in advanced stages of development, whereas others remain conceptual. Computer-aided antilock braking systems, an automated feature, have been in widespread use for several years. Collision warning devices, such as blindspot detectors, have found niche applications in some commercial fleets.

Adaptive cruise control systems, which include radar braking, may be introduced abroad within the next few years.[1]

The following section presents an overview of several intellgent and automated vehicle features and systems. Some are concepts; others are being developed and, in some cases, offered commercially. The study committee has not examined their technical feasibility or prospects for implementation. The main purpose of the discussion—drawn from descriptions provided by NHTSA and the National Automated Highway System Consortium (NHTSA 1997b; NAHSC 1997)—is to indicate the variety of advanced features and systems that are being explored.

Partially Automated Systems and Their Precursors

Concepts for partially automated driving fall into three groups: technologies that give drivers information, notifications, and warnings; those that take limited control of the vehicle in emergency situations; and those that automate certain routine aspects of driving but rely on manual control for most driving functions. Systems that make up the first group, some of which are being offered for sale in the United States and abroad, sometimes are viewed as precursors to systems in the second and third groups. In each case, various technological options are available, from sensors on-board the vehicle (e.g., radar) to radio communications between vehicles in traffic and between vehicles and the roadway infrastructure.

Notification and Warning Systems

These systems—some of which already are operational—would alert the driver to a threatening condition, allowing him or her to respond as appropriate. Advanced versions might give advice on suitable response options—for instance, suggesting braking or steering actions. The driver would be fully responsible for vehicle controls and could deactivate the warning system as desired.

Several emergency warning features are conceivable; some are now being offered commercially. A frontal warning feature, for instance, could detect when a vehicle is too close to the one immediately ahead, warning

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[1] When the term "automation" applies is a matter of debate because different advanced features offer not only different degrees of automation but different kinds. For instance, collision warning systems may not automate vehicle controls but they do automate driver information acquisition. No attempt is made here to precisely define automation. This may result in some imprecision in the discussion, which the committee accepts for the general purposes of this report.

the driver when the distance equals a predefined limit for the travel speed. The system would judge the rate at which the distance in front is decreasing and give increasingly urgent warnings about the possibility of collision. A side-looking or blind-spot warning feature, employing sensors on the side of the vehicle, could detect the presence of a vehicle in the adjacent lane. If the driver were to indicate a desire to change lanes—for instance, by using a turn signal—an audio or visual alert would be given. A lane-departure warning feature, which would use sensors to detect the position of the equipped vehicle in relation to lane markings or the roadway shoulder, would warn the driver as the vehicle approached or exceeded the lane boundaries. Warnings could increase in intensity as the vehicle drifted closer to the lane edge.

Other warning systems might serve as precautions. For example, a curve approach warning system might alert a driver of a difficult curve ahead, sending notification if the vehicle is approaching the curve at excessive speed. Roadway geometric information of this sort might be obtained from roadside communications beacons. Similarly, surface-condition warning systems might detect when tire-road friction, and therefore skid resistance, is reduced because of water, ice, or other road surface conditions. As road surface conditions worsen, increasingly strident warnings could be provided.

Other systems might detect and notify the driver of incidents, obstacles, or stopped vehicles in the roadway—perhaps communicated from a traffic management center, roadside traffic monitoring devices, or other vehicles in preceding traffic. On-board monitoring systems might detect driver drowsiness or degradation in the vehicle's safety-related systems and components, such as a loss in tire tread or pressure.

Temporary Emergency Controls

The foregoing warning and information systems might be expanded and modified to include emergency control features that would be activated when the driver fails to respond to a warning or when the time to respond is limited. These controls would help drivers avoid crashes or lessen their severity by enabling drivers to take evasive action. For instance, a frontal collision avoidance feature might detect when the distance between vehicles had closed to the point where a collision would result unless brakes were applied; if the driver failed to respond, the system could apply the brakes. Likewise, side-collision and lane-departure avoidance systems that exert emergency control might evolve from first-generation warning systems.

Partially automated controls also might be designed to prevent common kinds of driving mishaps. For example, a vehicle approaching a curve at an excessive speed could trigger the vehicle's accelerator to provide significantly greater than normal resistance, encouraging a reduction in vehicle speed. If a crash were imminent, the system could slow the vehicle as it approached the curve.

Continuous Partial Controls

In contrast to warning systems and emergency controls, partial automation applications might offer drivers continuous assistance with certain routine or repetitive driving tasks. With these systems, the driver would retain control of the vehicle generally but relinquish primary control of some driving tasks. The driver also would have the ability to revert to manual control as necessary.

Adaptive cruise control systems currently are being developed by some automobile manufacturers and their suppliers. Conventional cruise control systems—normally used during freeway driving—simply maintain vehicle speed at a level set by the driver; only the driver can change the speed from the preset level. Advanced cruise control systems would employ forward-looking sensors so the vehicle would be capable of adjusting speed to maintain a safe following distance from the vehicle in front. The vehicle would follow at a speed and within a headway parameter set by the driver, slowing when necessary to maintain a safe headway.

Another routine driving task that might lend itself to automation assistance is lane-keeping. Sensors on the vehicle would determine the position of the vehicle relative to lane boundaries, roadway shoulders, or special instrumentation installed in the roadway (e.g., magnetic markers). Using these cues, the lane-keeping system would keep the vehicle in the center of its lane by controlling steering and making other adjustments.

Lane-keeping systems used in combination with advanced cruise control would significantly reduce the role of the driver; these systems generally are regarded as crossing the threshold into fully automated operations.

Fully Automated Highway System Concepts

Fully automated driving often is described as “hands-off, feet-off driving” because the driver is fully disengaged from all, or virtually all, driving tasks. Presumably, some partial-automation features, such as obstacle detection, could be employed when fully automated operations are not engaged.

NAHSC grouped full-automation concepts according to several key attributes, particularly the degree to which vehicles and infrastructure work together to enable full automation. The following scenarios illustrate how fully automated driving could be achieved in alternative ways that rely to varying degrees on vehicle and infrastructure cooperation.

Independent Vehicles Operating Automatically

The first scenario assumes that fully automated vehicles operate along with manually driven vehicles, often traveling in the same lanes. Fully automated vehicles would employ sensors (e.g., optical and radar), computers, and other onboard systems. Neither infrastructure assistance nor communication with other vehicles would be required. Deployment therefore would depend on when such vehicle-based technologies are affordable, effective, and safe. Fully automated operations might ensue through gradual implementation and integration of partial automation systems, such as lane-keeping and collision avoidance systems. Construction or conversion of lanes dedicated to fully automated traffic would not be necessary. Because of mixed traffic and lack of coordination among vehicles, tight spacing of vehicles and increased speeds probably would not be possible—reducing the potential for significant gains in traffic throughput. Mixing of fully automated and nonautomated traffic also would raise many concerns about human factors and traffic safety and management.

Cooperating Fully Automated Vehicles

In the second scenario, vehicles equipped with onboard sensors and computers would share information with other vehicles to coordinate maneuvers and enable fully automated travel. Fully automated vehicles would have sufficient sensing, computing, and communications capabilities to work cooperatively in achieving close headways, detecting and avoiding obstacles, and coordinating responses to contingencies as they unfold in traffic. Though some infrastructure support, such as radio repeaters and controllers to relay and boost signals, might be needed to aid communications, vehicle-to-vehicle interaction would be the primary means of automatic control. Dedicated travel lanes might or might not be required; only where nonautomated traffic were excluded, however, would highly orchestrated and efficient traffic flows be likely (e.g., by coordinating lane changes, merging, and hazard warnings) to permit large gains in throughput.

Infrastructure-Supported or Assisted Fully Automated Driving

The third scenario envisions fully automated vehicles operating on dedicated lanes, using infrastructure instrumentation, intelligence, or both to enhance operations. The roadway would have an important, possibly active, role in the control of vehicle movements and overall traffic flows. Fully automated lanes would be physically separated from manual traffic by fencing, barriers, or medians, which also would exclude debris, animals, and other obstacles. Using dedicated lanes would reduce the potential for outside interference and allow faster vehicle speeds and closer spacings to increase throughput substantially, with traffic moving in coordinated platoons of fully automated vehicles. With such infrastructure support—and the economies of scale realized in providing it—the need for more expensive vehicle-based technologies could be reduced. The construction of new lanes might be required, however, or existing lanes would need to be converted for use by fully automated traffic.

Each of these generic concepts raises issues with respect to safety, traffic operations, and the environment, as well as other technical and practical considerations.

ISSUES ASSOCIATED WITH FULLY AUTOMATED DRIVING

Full automation concepts not only differ from one another in their technical feasibility, they also are likely to have different impacts on highway safety and capacity, as well as their own sets of environmental, financial, and societal implications. For example, fully automated vehicles operating in platoons on protected and dedicated travel lanes (as in the third scenario) could lead to large gains in traffic throughput because vehicles could be closely spaced and driven at high speed. To achieve this added throughput, however, significant investments might be needed in building or converting lanes to handle fully automated traffic. Such investments might prove financially and politically difficult for many jurisdictions. On the other hand, fully automated vehicles operating autonomously (that is, without dedicated lanes, as in the first scenario) might require minimal public-sector investment in new infrastructure but would be more expensive to motorists.

These kinds of trade-offs would require careful examination and balancing before a preferred fully automated highway system could be specified. Such consideration, however, requires a thorough understanding of the impacts and trade-offs and the ability to weigh and value them from a societal standpoint. The safety effects of alternative concepts, for instance, would need to be assessed and weighed against their respective traffic throughput and environmental impacts; public-sector versus private-sector investment requirements would need to be considered and balanced; and so forth. Judgments such as these often are made in the marketplace or through political and public policy processes.

As Box 3-1 shows, the specification of a fully automated highway system raises complex safety, environmental, and institutional issues. These and other issues have been the subject of investigation by DOT and the NAHSC program. Perhaps the most difficult aspect of specifying a fully automated highway system is gaining consensus on these issues and their relative importance.

BOX 3-1: DESIGN AND IMPLEMENTATION ISSUES FOR FULL AUTOMATION

System Safety and Public Acceptance
To ensure user acceptance, a fully automated highway system must be designed and implemented with many complex human factors and operational reliability considerations in mind. For instance, decisions about which vehicle controls are automated and how these systems interface with the driver will affect system safety. The extent to which motorists would accept reduced manual control of their vehicles or be willing to travel in automated vehicles at close following distances, on narrower lanes, and at higher speeds is unclear. The potential for multiple-vehicle crashes, with catastrophic consequences, may require safety design and management methods analogous to those required for air travel.

Overall Effects on Environment and Traffic
A change in the surface transportation system as significant as that envisioned for fully automated highways would have many ramifications; for example, it might affect where people live, commute, and socialize, as well as energy use and emissions. A faster, more efficient highway system might enable commuters to live farther from city centers—leading to increased land development and urban encroachment into rural and wilderness areas. Increases in total travel might cause aggregate fuel use and emissions to rise even if automated driving proves to be more energy-efficient. The effects of increased traffic capacity and volumes on automated highways would have implications for traffic levels throughout the system. Automated roads might divert traffic from nonautomated roads; they also could increase traffic on surface streets near exit and entrance points.

BOX 3-1 (*continued*)

Political and Institutional Issues
Many practical issues arise in considering the role of state and local governments in building and operating automated highways. For instance, can state and local transportation agencies—burdened with maintaining existing networks of aging highways—be expected to build, maintain, and operate a much more sophisticated system of automated highways? Likewise, is it reasonable to expect state and local jurisdictions to work together effectively in planning and operating automated highways? If many motorists cannot afford automated vehicles, will it be politically feasible to dedicate lanes to automated traffic?

Liability Concerns
Tort liability will affect the kinds of automated systems developed and deployed. Most automobile liability cases today involve motorists (or their insurance companies) suing one another over crashes; this situation exists because most crashes are caused by driver error, not equipment failures or flaws. The introduction of automated controls in vehicles and highways could fundamentally alter tort liability because the design, construction, and operation of automated systems would have a more direct impact on motor vehicle safety. The significance of the liability concern presumably would depend on, and influence, the kinds of automation systems that emerge.

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ABBREVIATIONS

DOT	U.S. Department of Transportation
FHWA	Federal Highway Administration
NAHSC	National Automated Highway System Consortium
NHTSA	National Highway Traffic Safety Administration
TRB	Transportation Research Board

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