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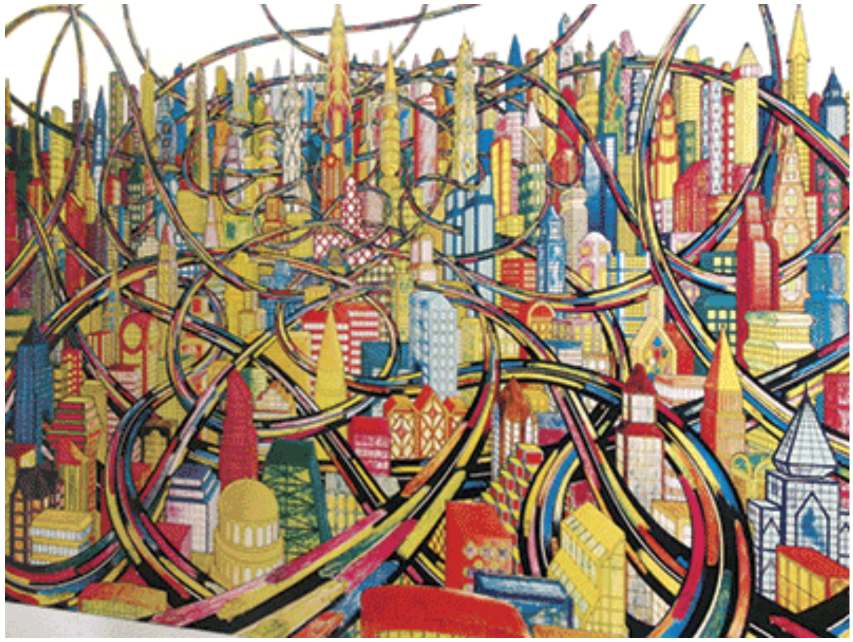
The Dream of an Automated Highway

by Robert A. Ferlis

The new technologies described in this futuristic scenario offer a realistic forecast of the state of transportation in 2050.



This painting by Joseph A. Barbetta, completed in 1990, is titled HIGHWAYS and offers a fanciful vision of what the urban highway system of the future might look like.

The General Motors *Futurama* exhibit at the 1939 World's Fair in New York featured a vision of technologically advanced superhighways where cars would navigate curves at speeds up to 80 kilometers (50 miles) per hour using "automatic radio control" to maintain safe distances. Cities would have elevated walkways where pedestrians could travel safely without being endangered by the vehicle traffic beneath them. Hundreds of thousands of visitors were mesmerized by this dream of new cities with gleaming skyscrapers, spectacular highways, and the promise of greater mobility. Sound unbelievable? This vision in the late 1930s pictured the transportation system as it would be in 1960, only 21 years into the future!

The *Futurama* exhibit was such a huge hit that General Motors hosted *Futurama II* at the next New York World's Fair in 1964. In the "near future," according to *Futurama II*, the "City of Tomorrow" would eliminate all traffic problems by building urban living centers above advanced freeways, where computer-guided vehicles would travel swiftly, safely, and efficiently. Moving walkways would carry pedestrians quickly and safely to shopping areas and other attractions. To make this vision a reality, a five-story-tall, atomic-powered road-building machine would construct 1.61 kilometers (1 mile) of elevated, four-lane freeway every hour, 24 hours a day. Without regard for environmental concerns, a 30.5-meter (100-foot)-long laser tree cutter preceded the road builder, spraying the cleared areas with chemicals to retard future growth. Dazzling cities sprang up out of the jungle on either of side of the giant road-building machine.

More recently, the Intermodal Surface Transportation Efficiency Act of 1991 authorized the U.S. Department of Transportation's (USDOT) Automated Highway System (AHS) program to "develop an automated highway and vehicle prototype from which future fully automated intelligent vehicle-highway systems can be developed" to demonstrate the vision and technology needed to make highway driving more efficient, safe, and predictable.

The AHS program spearheaded formation of the National Automated Highway System Consortium (NAHSC) to carry out this vision. The NAHSC included such transportation stakeholders as automobile manufacturers, infrastructure builders, and State and local transportation agencies, and was assisted by top-level academic transportation centers and engineering, communications, and aerospace firms. The work of the NAHSC culminated in August 1997 with an AHS proof-of-concept demonstration on I-15 in San Diego, CA, where more than 20 fully automated vehicles operated flawlessly for 4 days on two protected lanes (normally the HOV lanes) that had been blocked off from other traffic. The demonstration provided participants with a "hands-off, feet-off" driving experience and gave the public a tantalizing taste of the future.

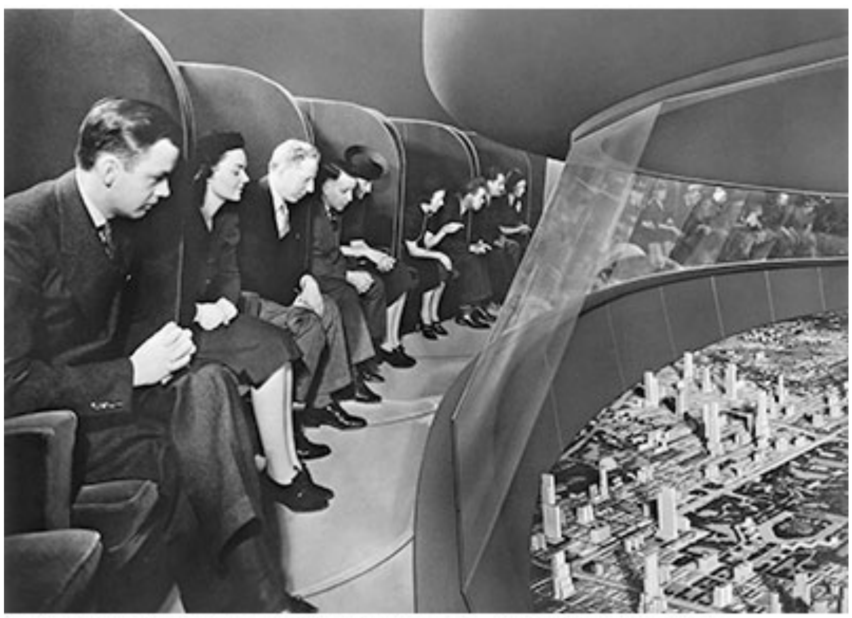
Although the AHS program ended with the 1997 demonstration, automated highway concepts continue to emerge from various sources. For example, some futurists have suggested that placing cars on trains could offer significantly greater efficiency and have proposed innovative mechanical methods to facilitate critical intermodal transfers. Others have proposed underground automated highways, which would involve digging connector tubes between major urban areas or within the metropolitan areas themselves.

Proponents of the automated highway envision that the concept could solve transportation problems within a 2030 to 2060 timeframe. Others disagree. Some transportation experts consider the concept to face considerable challenges and believe that it is unlikely to be technically, commercially, or environmentally viable, even in the distant future.

What Happened to the Automated Highway?

Despite the potential for dramatic mobility and safety benefits, automation of the driving task has proven difficult to achieve. The technological challenges of automation seemingly would require that vehicle systems be designed to incorporate the full information available to a human driver with the same level of intelligence.

In response to this challenge, some engineers have approached automation by simplifying the environment to make automated systems easier to achieve. The automated highway system that was the focus of USDOT's AHS research in the 1990s and the subsequent I-15 demonstration, for example, were based upon protecting the vehicle from unexpected incursions by people, animals, and other vehicles by providing a physically protected roadway. The control systems then could be designed to address "known" problems such as keeping the vehicle in the lane, safely following preceding vehicles, and bringing the driver back into control at the exit from the designated roadway. The AHS I-15 test successfully demonstrated the technological feasibility of this approach.



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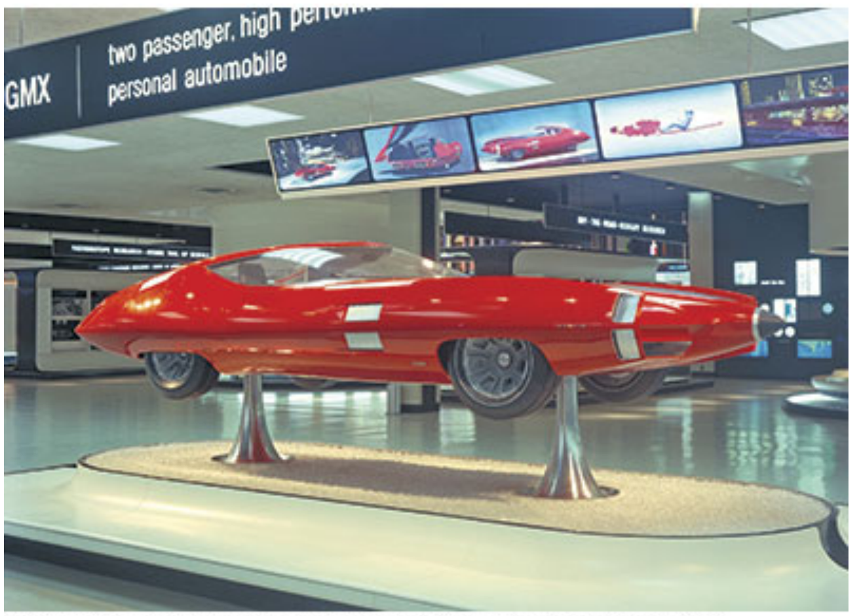
At the 1939 World's Fair, attended by nearly 45 million people, these visitors to GM's Futurama exhibit sat in traveling chairs where they "toured" a model panorama of the country as it might appear in 1960, experiencing the "sensation of traveling hundreds of miles" and seeing the future as if from a low-flying airplane.

Seven technical and institutional challenges, however, remain. First, as learned from the AHS demonstration, a major challenge to deploying automated highways is the need for protected, dedicated lanes that provide a manageable and extremely reliable environment for safe automated travel. The dedicated lanes would require a communications system capable of real-time management of traffic and would increase construction costs, thus limiting the set of major highways where the needed infrastructure could be provided. The need for dedicated lanes would complicate the distribution of automated traffic, as existing streets will not be capable of accommodating so many additional vehicles. For example, special facilities might be needed to allow for the circulation and parking of automated vehicles once they leave the automated highway for city centers and other destinations.

Second, an AHS has to be designed so that it will be accepted by drivers and will be used effectively. The actual public experiences of AHS technologies during the demonstration in 1997 were overwhelmingly positive, with almost everyone finding that their confidence in the potential of automated driving improved as soon as they experienced it. But significant design challenges remain to ensure that drivers will be able to use the AHS safely and effectively under all circumstances. Significant human factors studies will be needed to design the AHS to deal with situations that include transitions between manual (normal today) and automated travel modes, and the potential need to intervene in emergency situations.

Third, the complexities of automated driving systems will require vehicle and highway systems that operate at a higher level of reliability and performance than today, and with new management and operating systems to allow that increased performance. Highways that support AHS will require much more sophisticated communication and control systems, and these systems will in turn require additional skills, attention, and time from the human operators. But this challenge has been overcome in other industries, such as electric power distribution, and can likely be overcome for AHS as well.



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This futuristic-looking, twopassenger automobile was part of GM's Futurama II exhibit at the New York World's Fair in 1964. A press release noted that one of the futuristic cars at the exhibit "anticipates the day when the family will drive to the super highway, turn over the car's controls to an automatic, programmed guidance system and travel in comfort and absolute safety at more than twice the speeds possible on today's expressways."

Fourth, institutional challenges are likely to include increased liability for manufacturers and owner/ operators of automated systems. Even though automated systems are expected to offer significant safety benefits compared with human driving, technological failures potentially could result in new problems. Careful product design and development could reduce manufacturers' risks through contingency plans in case of electrical or system failure, and adherence to design standards potentially could decrease unforeseen consequences. Also, a new paradigm of driver and highway owner/operator responsibility might need to be developed to recognize the overall societal benefits and the different risks that might result from an automated system. Insurance policies could, for example, provide affordable new coverage based on the risks of automated driving being lower than the current risks of human driving errors.

Fifth, the phenomenal growth of truck traffic and the significantly different handling and operating characteristics of commercial motor vehicles present real challenges to accommodating commercial vehicle operations on an automated highway. Truck traffic is growing faster than automobile traffic. Based on an analysis of data in the Federal Highway Administration's (FHWA) Freight Analysis Framework database, urban interstates now are estimated to handle more than 9,300 freight-carrying trucks on any given segment on a daily basis. By 2035, the number of trucks will jump to more than 21,000. Trucks moved approximately two-thirds of the tonnage and the value of the goods moved in 2002. They moved this quantity due to the current diversified distribution patterns and service requirements. Any attempt at automating roadways will have to take mixed car and truck traffic into consideration.

Sixth, perhaps the greatest challenge would be the cost and deployment itself. Major investment, most likely in the billions of dollars, would be needed all around — from the public, automobile manufacturers, automobile dealers, infrastructure investors, and others. On the part of manufacturers, investments would be needed to redesign vehicles, create and retool factories, ramp up distribution channels, and train third-party vendors in servicing. Enough drivers would need to purchase sufficient automobiles, especially because the introduction of new innovations to a market generally tends to cost the early adopters more money. Large public-private investment would be needed to rehabilitate existing infrastructure or add dedicated lanes. The sheer volume of investment necessary to create this network could be staggering.

Deployment of the dedicated lanes, communications infrastructure, and vehicles that can make use of these assets must be synchronized so that the automated highway system will work as intended. Dedicated lanes likely will be underused until vehicles capable of supporting automated driving are purchased by a sufficient number of drivers. If the automated lanes are new construction, they undoubtedly will be underutilized for some time. If converted from existing lanes, congestion on other lanes would be aggravated in the short term.

One approach to achieving automation is to distribute the driving functions. Automated control systems would perform some routine tasks, and perform them better than human drivers, but would rely upon humans for unexpected events that they could respond to more appropriately. This approach requires continued vigilance by the driver, which can be questionable when the driver is not engaged continuously in the driving task.

Finally, the last challenge is environmental. The inherent capability of an automated highway to accommodate much more travel efficiently could encourage more travel and aggravate existing tendencies for urban sprawl, as people will be able to travel farther. The tradeoffs between the advantages to travelers and the resulting environmental costs must be weighed in terms of public policy, much as the construction of new freeways is today.

The challenges discussed above likely will be overcome eventually as the performance of automated systems more closely replicates all aspects of human driving performance. For example, computer vision and intelligent systems processing can be expected to improve over time and eventually may far exceed the performance of a human driver. Improved technology thus could eliminate the need for physically separate lanes and hence simplify deployment staging and potentially reduce costs.

Can Tomorrow's Highway Overcome Congestion?

Because transportation in 2050 certainly will be quite different from today, the transportation community can only speculate on the differences. Even if the highway of tomorrow does not realize the potential of fully automated driving, transportation agencies still can make considerable progress in overcoming congestion through partially automated systems.

Although travel demand and freight movement will continue to increase, passenger car travel still will offer people enormous mobility opportunities through the use of technology and operational methods that will fundamentally alter how people drive.

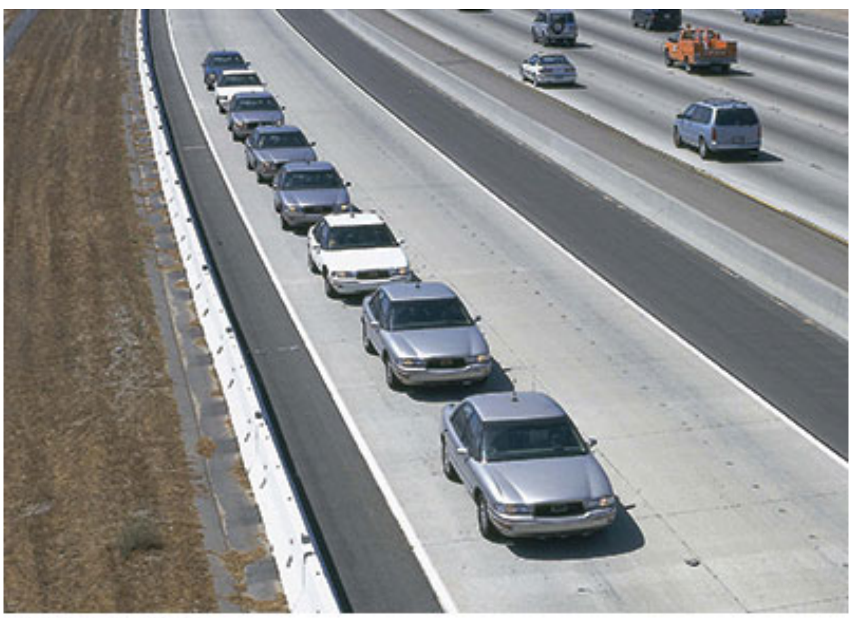
Communications technologies will be important in the future highway system. The early automated driving technologies relied upon a strong central processing capability, depicted in some cases as similar to an airport's control tower, where specific directions were conveyed by radio to drivers who were expected to follow the directions much as pilots are expected to do. By the 1990s, the processing and communications model introduced by USDOT's AHS project distributed control so that management functions were conducted automatically and, depending upon function, were performed either centrally, for groups of vehicles (platoons), or within individual vehicles.

In the future, the transportation community can expect further evolution so that vehicles will be even smarter, with vastly improved sensing and processing systems, and can communicate even more extensively. Vehicle-vehicle and vehicle-infrastructure communications systems will be available on all vehicles traveling on major highways and arterials of the future.

The evolving Vehicle Infra-structure Integration (VII) initiative includes a consortium that consists of automobile manufacturers, 10 State departments of transportation, USDOT, and the American Association of State Highway and Transportation Officials. The VII intends to deploy fundamental communications technology for vehicle-roadside and vehicle-vehicle communications through multiple communications platforms that will support future highway travel.

AHS Demo on I-15

One of the scenarios in the 1997 demonstration of the Automated Highway System (AHS) on **I-15 in San Diego, CA,**featured "platoons" of eight fully automated cars in a tight and coordinated formation — only 6.5 meters (21 feet) apart — and traveling at nearly 105 kilometers (65 miles) per hour. The demonstration showed members of the public how feasible, and personally acceptable, automated driving could be. The platoon concept offered drivers convenience and greater safety, while at the same time allowing up to two to three times as many vehicles to use the freeway lane as compared to today.



California PATH

In the 1997 demonstration of the AHS on I-15 in San Diego, CA, these eight cars were driven by a fully automated system in a tight formation at highway speeds.

Improved communications systems, complemented by expected advances in sensors and processors on vehicles, will provide cooperation between vehicles, which will facilitate many new services. For example, vehicles will be able to follow other vehicles more closely, and yet more safely, than they can today. This improved technology will enable at least two or three times as many cars to use freeways and arterials in the future, greatly increasing the capacity and efficiency of the existing highway system. All vehicles will travel at the fastest speed allowed for the facility at that time, as determined by a traffic management system that will balance demand and performance at the highest level. The resulting traffic flow will be much greater, and safer, than it is today, so that recurring congestion on freeways could all but disappear.

On arterial streets, traffic signal systems still will control traffic flow but will incorporate advanced algorithms that will communicate the signal timing data to vehicles and their drivers. Motorists will make use of the timing data to improve their progression and avoid the need to stop in most cases. Even if stopped, vehicles will start again automatically and will follow other vehicles in the queue more closely, allowing more cars to be accommodated faster and more safely than today. These advances will permit much smoother traffic flow, thereby easing the driving task and providing more efficient operation.

On tomorrow's superhighways, the driver's tasks will be easier than they are today. Some vehicles will be driven automatically, so the vehicle's owner will not have to steer and can do other productive tasks. Automation of some commercial driving functions will reduce costs, enhance service, and expedite the handling of goods at origin, transfer, and destination.

Tomorrow's Highways Will Improve Travel Reliability

Nonrecurring congestion will be reduced through new technologies. Smoother traffic flow will prevent many crashes that cause nonrecurring congestion. In addition, vehicle mechanical failures will be reduced dramatically by onboard diagnostic and correction features. Proactive identification of possible mechanical problems by the vehicles themselves, and automatic communication with repair services, will reduce the possibility of "random" mechanical failures that can strand motorists and cause safety and traffic flow problems for other drivers.

Any mechanical failures that do occur will be identified immediately by onboard vehicle systems and communicated to emergency responders and traffic management authorities so that help can be provided quickly. Information on the problem, and potential route guidance suggestions, then can be provided automatically to other drivers through their own onboard vehicle systems, so that most of the safety and delay consequences of the incident can be avoided.

The VII Initiative

To improve transportation and the quality of American life, the Vehicle Infrastructure Integration (VII) initiative envisions a nationwide deployment of a communications infrastructure on the roadways and in all vehicles. With VII, crash prevention and congestion relief could be facilitated through vehicle-vehicle and vehicle-roadside communication.

The VII initiative will build on the availability of advanced vehicle safety systems that were developed under USDOT's Intelligent Vehicle Initiative and were based on the results of related research and operational tests. It also will be supported by a newly available radio spectrum provided specifically to support advanced safety applications being planned under VII as coordinated deployments of communication technologies in all vehicles by the automotive industry and on all major U.S. roadways by the transportation public sector.

Under VII, data transmitted from the roadside to the vehicle could warn a driver that it is not safe to enter an intersection. Vehicles could serve as data collectors and anonymously transmit traffic and road condition information from every major road within the transportation network. Such data would provide transportation agencies with the information needed to implement active strategies to relieve traffic congestion. A VII consortium has been established to determine the feasibility of widespread deployment and to establish an implementation strategy.

A new intersection collision avoidance concept is demonstrated at FHWA's Turner-Fairbank Highway Research Center in McLean, VA, during the Intelligent Vehicle Initiative National Demonstration in June 2003. The communication between the vehicle and the traffic signal needed to warn the driver of a possible signal violation would be enabled by deployment of VII technologies.

Can Many Crashes Be Eliminated?

New technologies will eliminate many crashes, dramatically reduce injuries and fatalities, and make highway travel much safer than it is today. Today's cars and highways strive to minimize the effects of a crash when it occurs. Tomorrow's cars and highways will prevent the crash altogether.

- Communications between the vehicle and the infrastructure will reduce intersection collisions by warning drivers of likely traffic signal violations and then helping them maneuver safely through the intersection. If a crash is imminent, the vehicle will apply the brakes automatically to stop safely before a crash occurs.
- Advanced run-off-the-road and curve warning systems will help prevent the driver from leaving the roadway — a major cause of crashes and fatalities today, particularly in rural areas.
- Rear-end crashes will be significantly reduced because vehicles will communicate with each other and will recognize, before a driver could, that the leading vehicle is stopped or stopping too fast for a following vehicle to avoid. The onboard system will warn the driver to take evasive action and will brake automatically, if necessary, to avoid the crash.
- Similarly, through communication and sensors, vehicles will know where they are, where they are heading, and possibly whether people or animals are in the roadway. This technology will enable the vehicles to maneuver to avoid potential conflicts so that such collisions will be avoided.
- Should a crash occur, onboard vehicle systems will alert emergency responders immediately, providing the crash location and other advance information that will improe a responder's ability to provide assistance.

These systems will reduce significantly, and possibly almost even eliminate, the major types of vehicle crashes.

How Will the Driver's Role Change in the Future?

Future mobility and safety benefits will be achieved not only through technology and operational improvements, but also through fundamental changes in how drivers access and use the highway systems of the future.

Improved technologies will allow many more vehicles to use a freeway or arterial street than today. But there always are limits, so demand still must be managed in the future, too. Because vehicles and traffic management systems will be in constant communication, the highway systems will know how many vehicles can be accommodated effectively at any time and will allow only that many vehicles to use the highway. But how could this be done?

In the car, the driver could submit a route request through the car's navigation system, or possibly the car itself might recognize a personal travel pattern automatically and order an optimal route for the driver. Comparable systems could be available for commercial motor vehicles. Travel requests also can arise as the traffic management system recognizes opportunities to route, or reroute, trips based on expected demands or incidents.

Tolls may be charged for facilities where demand exceeds supply and can be varied to allow more effective utilization of the highway system. Drivers will always be kept "in the loop" by direct communication of travel information, including any expected toll charges, and they can alter their travel plans accordingly. Pervasive communication will enable drivers to receive needed information in advance of their trip, or during their trip as needed, rather than being surprised right before they enter the toll facility.

Planning trips will be much easier in the future. Advances in information processing, and associated behavioral changes, will allow travel requests to be generated effortlessly, as people will essentially be able to talk to their personal information devices or vehicles. (Verbal request: "*Planning to drive to Aunt Rosie's in an hour or two...OK?*" Response: *"No problem. I'll reserve a slot for you on the Smithtown Automated Freeway at 3:00 p.m. The toll will be $8."*) Vehicles also will monitor actual driver behavior as needed and will be able to interact with the traffic management center "behind the scenes" so that drivers are not bothered or distracted, but traffic still can be managed. (Arriving at the Smithtown Freeway at 3:10 p.m. should be "no problem," but arriving at 5:00 p.m. might be.)

How Will Transit and Pedestrians Fare in the Future?

Transit services also will evolve and become much more pervasive in the future. Travelers can expect that more trips will be made on transit services of some kind, reflecting more transit-friendly land use patterns and technological and service innovations that will permit a more convenient, reliable, and faster trip. Major investments in quality regional transit services, such as provided by rail or bus rapid transit, can be anticipated, as land use patterns will enable more trips to be served and transit services to "catch up" with currently ill-served areas, such as recently developed suburbs.

Transit services have significant potential to benefit from specialized automation services. Automation will enable some transit services to use automated control so that the enormous costs of driving can be reduced or avoided, and flexibility in offering peak-period services can improve. In addition, the more efficient and economical services allowed by automation can help extend transit to areas that could not previously be served, including low-density residential neighborhoods where competitive services (in frequency, location, and cost) could not be provided previously to link homes with regional transit and local activity centers.

In addition to the dramatic changes in future transportation technology and automation, more people will be able to walk or bike to their destinations. Land use patterns characterized by "new urbanism" and transit-oriented development will provide greater opportunities for people to make short trips by bicycle or on foot, and will help communities to improve pedestrian and bicycle facilities. Future traffic management and vehicle control systems increasingly will permit greater safety, reliable security, and faster travel within communities, as these systems will recognize pedestrians and bicyclists and accommodate them at traffic signals and other conflict points.

So What Can We Really Expect in 2050?

Although the transportation system of 2050 will almost certainly not achieve the full vision of the *Futurama* City of Tomorrow, there is every reason to believe that future transportation management systems and sophisticated new vehicles will provide a safer, faster, and more convenient driving experience that the transportation community can only dream of today.

Robert A. Ferlis is technical director of FHWA's Office of Operations Research and Development. He currently serves on the working group for the evolving VII initiative, where he is developing applications to take advantage of VII technologies. He has conducted research in vehicle-highway cooperation and collision avoidance systems. Before joining FHWA, he worked as a transportation research consultant and as a systems manager. He received a B.S. in systems engineering from the University of Illinois and an M.S. in civil engineering from Northwestern University.

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