Thomas J. Bamonte

Drivers of Change

Highway authorities need to start preparing now for the inevitability of driverless vehicles

Driverless-vehicle technology has been a gleam in the eye of futurists since not long after the Model T revolutionized our surface-transportation system.

GM's Futurama exhibit at the 1939 World's Fair featured driverless vehicles. For decades, researchers labored to bring the vision to reality. Many of the driverless-vehicle prototypes contemplated "dumb" vehicles and "smart" infrastructure. Magnetic or electronic guide ways built into highways would control vehicles while the occupants presumably relaxed and fiddled with their transistor radios.

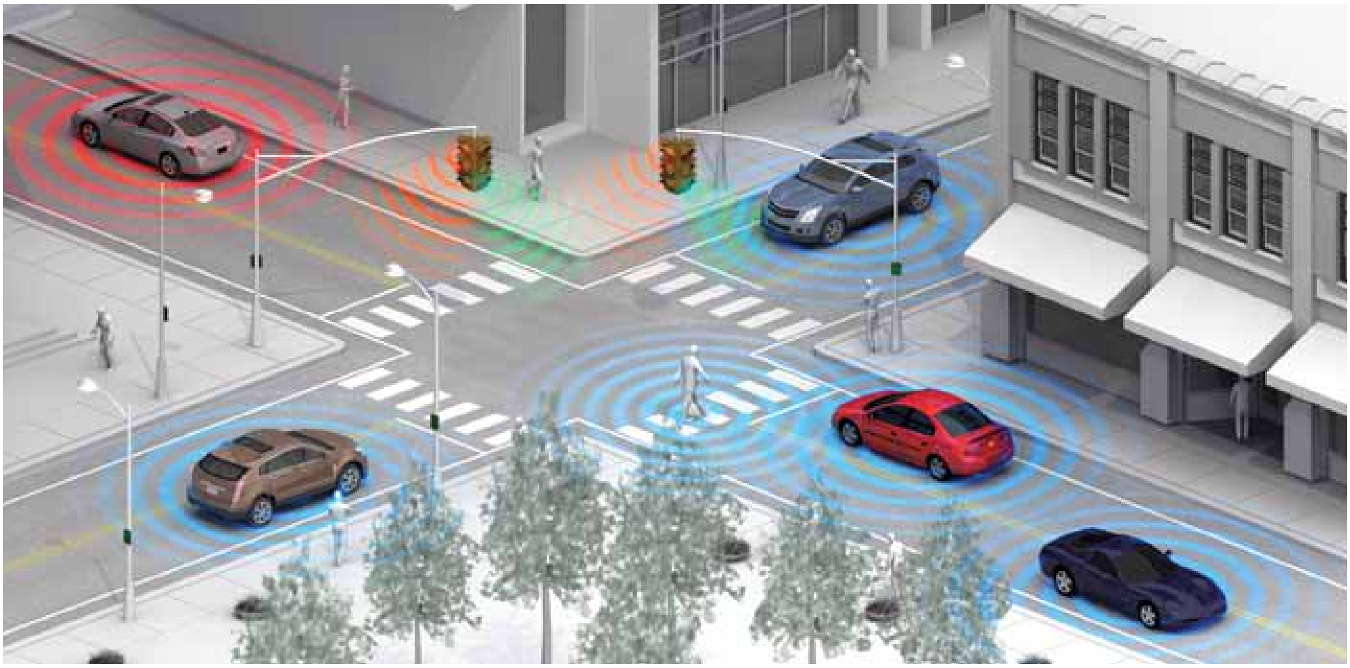
Given the many unmet promises over the decades that driverless vehicles were just around the corner, many are properly skeptical that the current wave of excitement over the Google car and other driverless-vehicle prototypes will yield anything tangible.

Yet, it appears that advances in microprocessors, sensors, cameras, GPS and other technologies will finally make driverless vehicles a viable part of our transportation system—and soon. Driverless vehicles will fundamentally alter our transportation system. Infrastructure providers such as highway authorities and private companies will face profound challenges and opportunities that match those faced a century ago when we shifted to primary reliance on the automobile for surface transportation.

Despite the safety and other benefits likely to result from driverless-vehicle technology, highway authorities did not invest in building such driverless-vehicle-based infrastructure. Nor were vehicle manufacturers interested in the technology, which they saw as adding cost and little benefit to the users. Consumers, who for decades subscribed to romantic notions that driving was "cool," did not push for technology that would take the steering wheel from their hands.

Out from behind the wheel

Much has changed and those changes mean widespread deployment of driverless-vehicle technology is all but inevitable. A rapidly growing class of consumers value connection with the Internet more than the "freedom" to drive day after day on often-congested highways. For these people—perhaps most of us by now—driving is the distraction that keeps us from texting and otherwise



Driverless-vehicle innovators are not waiting for transportation authorities to build "smart" highway infrastructure. They are confident that the pressure of innovation will prompt infrastructure providers to deliver technology to the roadway. Graphic courtesy of GM.

connecting via the Internet. There is thus a groundswell of demand for vehicles that will free up the occupants for Internet connectivity and spare them the mundane task that driving has become.

Auto manufacturers are responding to this powerful consumer trend by using driver-assist technologies to distinguish their brands. Vehicles are being equipped with self-parking features, collision-avoidance systems and lane-deviation correction technology. Auto manufactures are starting to roll out in consumer models semiautonomous technology packages. This is the intermediate step to driverless vehicles.

Demand for driverless vehicles is also coming from fleet operators, heavy-equipment users (e.g., mining, agriculture) and the military, all of which would benefit from driverless-vehicle technology in different ways. For example, existing technology developed by Volvo allows trucks to platoon by traveling only a few feet apart. The improved aerodynamics results in fuel savings of more than 10%.

New market entrants such as Google and a host of university-affiliated research centers around the world are working on the next steps that will yield a fully autonomous vehicle that can travel from point A to point B without occupant intervention. The Google car has logged roughly 500,000 miles successfully, and other autonomous vehicles are rolling out and being tested all over the world.

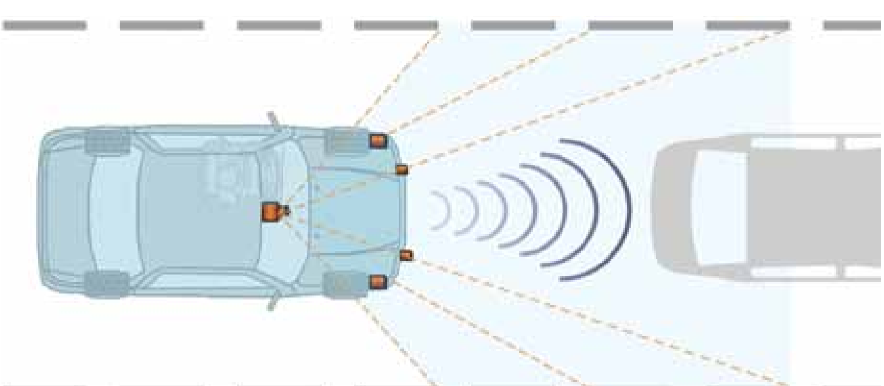
Safety concerns are an additional driver for the development of driverless-vehicle technology. There are about 1.25 million fatal vehicle accidents annually in the world. Such accidents are the leading cause of death worldwide among 15- to 29-year-olds. The cost of vehicle accidents in the U.S. alone is more than $250 billion annually. Most of these accidents are preventable using driverless-vehicle technology.

Conspicuously absent from the forces driving the development of driverless vehicles are infrastructure providers such as highway authorities.

In many metropolitan areas, highway capacity is not keeping up with population growth and the increase in vehicle-miles traveled as a result of such growth. Efforts to build out of the resulting congestion by physically expanding existing highways are underfunded and ultimately self-defeating. Driverless-vehicle technology offers a means to increase highway capacity within the existing highway footprint at less cost.

All of these trends are converging and will push driverless vehicles over the finish line. Doing so will allow consumers to stay connected and make driving time more productive time. Fleets will be more efficient. Safety will improve. Major new markets in hardware and software will develop, while some existing industries (e.g., taxi driver) will face obsolescence.

Conspicuously absent from this list of the forces driving the development of driverless-vehicle technology are infrastructure providers such as highway authorities. State departments of transportation are neither focused on nor invested in driverless-vehicle technology. It took the dramatic splash of the Google car to force the U.S. DOT to re-examine its multidecade commitment to incremental improvements, but no driverless vehicles. The U.S. DOT still does not have a central office devoted to automated vehicles. Whether the U.S. DOT will embrace such technology in race-to-the-moon-like fashion or continue slowly down its path of incremental improvements and resulting irrelevancy on the transportation technology front remains to be seen.



GM's Super Cruise does adaptive cruise control and lane centering, using cameras and sensors to automatically steer and brake in highway driving. Graphic courtesy of GM.

Vehicles in the lead

The tepid response of transportation authorities to driverless-vehicle technology is history repeating itself. Henry Ford and the network of vehicle-technology innovators a century ago did not wait to introduce the automobile until far-sighted governments built superhighways. Instead, they rolled out the horseless carriage in the existing environment, dirt roads and all, confident that consumer demand would prompt infrastructure providers to build the roadways and associated structures that were necessary to optimize the use of the automobile.

Driverless-vehicle innovators in a similar fashion are not waiting for transportation authorities to build out "smart" highway electronic infrastructure before rolling out their driverless vehicles. They are introducing driverless vehicles to the existing infrastructure environment, confident the pressure of innovation will prompt infrastructure providers

By supplanting the onboard human operator and shifting vehicle control over to electronics, driverless-vehicle technology destabilizes the legal and organizational regime in which transportation-infrastructure providers have functioned. Photo courtesy of GM.

to deliver technology and changes to roadway architecture that will optimize such vehicles.

At some time after the successful introduction of driverless-vehicle technology, "smart" infrastructure will likely assume some of the load currently being built into onboard-vehicle-technology platforms. It may be more efficient to build some functions into the roadway rather than equipping each vehicle with the full set of electronics and software necessary for driverless vehicles. At a minimum, roadway electronics may provide a backup when inclement conditions such as snow render onboard sensors ineffective.

This time, infrastructure providers will have to focus on providing new and better ways of communicating pertinent information to the electronic "brains" built into vehicles, and vice versa. When onboard and infrastructure technologies work together, the full potential of driverless-vehicle technology can be realized.

Destination unknown

Speculation about where driverless-vehicle technology will take us reads like it is lifted off the pages of science fiction, and deservedly so. This is transformative technology.

Driverless-vehicle technology will make highway travel safer. This will allow vehicles to morph from their current, tank-like safety protective design to lighter vehicles that will consume less fuel. Lighter vehicles in turn may accelerate the shift to electric and other propulsion technologies, which will have infrastructure implications (e.g., charging stations).

Some predict that because consumers can summon driverless vehicles from remote parking areas, they will no longer be inclined to buy and own a single one-size-fits-all vehicle. Instead, they will subscribe to vehicle-sharing services that allow them to order up vehicles in real-time that fit their needs, such as a single-seater for a solo shopping trip or a large van for a family trip. This shift from an ownership to a subscriber model may accelerate the proliferation of vehicle types, which will pose a challenge to licensing authorities that are comfortable with the current limited range of vehicle types allowed on our highways.

Driverless-vehicle technology gives new transportation options for the many millions of people in the U.S. alone who because of age (young and old) or physical infirmity are incapable of driving a vehicle currently. This cohort will be growing rapidly as Baby Boomers pass into old age and struggle to keep their prized mobility.

Highway efficiency is low with humans behind the wheel. The spacing between vehicles required because of human physiological limits of perception and reaction time leaves much of the highway empty. Driverless-vehicle technology will allow the gap between vehicles to shrink significantly, which will markedly increase the carrying capacity of our existing highways. Such technology may even allow the creation of more lanes in the existing footprint, although the very concept of lanes may be rendered obsolete by this new technology.

If the carrying capacity of existing roads can be markedly increased through driverless-vehicle technology, then the unrelenting pressure to build new roads and expand existing roads to address congestion will lessen if not cease altogether in many areas. When putting together long-range capital plans, transportation authorities need to begin considering the possibility that investing in infrastructure and organizational practices that facilitate the deployment of driverless-vehicle technology may be a better investment than pouring dollars into lane widening and new highways.

The land-use implications from driverless-vehicle technology could be profound. Some predict that by making auto travel more enjoyable, driverless-vehicle technology will encourage more driving and urban sprawl. Yet, by markedly increasing the carrying capacity of existing highways and reducing the need for on-site parking, driverless-vehicle technology will allow greater density development along highway corridors, possibly resulting in less vehicle use.

The cumulative impact of these developments could be that the proportion of land devoted to roads and parking will shrink in commercial and residential areas. Just as railroads today carry more freight on fewer rails and have excess right-of-way available for sale as a result, the footprint of highways, streets and parking may shrink, freeing up space for commercial and residential development, improved walking and biking transportation options and enhanced community amenities.

Driverless-vehicle technology may displace public transit in some areas, as people will prefer the flexibility of a driverless vehicle over a bus, while at the same time allowing population densities along highway corridors to increase significantly, making those areas more hospitable for public transit. There is active ongoing debate whether driverless-vehicle technology, including platooning capabilities, will displace or at lease make less attractive both passenger rail and air travel between cities that are a short haul apart.

In sum, driverless-vehicle technology will have a profound effect on how we travel, what we can do while traveling and the shape of our built environment.

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Benefits of investing in the future

Driverless-vehicle technology challenges the existing business model of transportation providers that has been in place for decades. That business model is based on public authorities delivering "dumb" infrastructure that is utilized by human drivers in direct control of vehicles. This system has stable parameters for things such as traffic-flow numbers that result from the interaction of those elements. A stable legal and organizational regime has grown up around these parameters.

By supplanting the onboard human operator and shifting vehicle control over to electronics, driverless-vehicle technology changes those elements and thus destabilizes the legal and organizational regime in which transportation-infrastructure providers have functioned. Change is hard, but inevitable if it turns out that consumers—and voters—embrace driverless-vehicle technology, which they seem likely to do.

From a technical perspective, transportation-infrastructure providers must figure out how infrastructure can assist the deployment of driverless-vehicle technology. This will require highway authorities to understand how driverless vehicles "see" and how infrastructure can be customized to make it more visible to such vehicles, especially during inclement conditions such as snow or fog that may confound onboard technology. Making infrastructure more visible to vehicles—not necessarily to the naked eye—by giving infrastructure elements such as bridge piers an electronic signature will help optimize highways for travel by driverless vehicles. There may be ways to improve existing visual elements, such as lane markings, so that driverless-vehicle technology works better.

Communications capabilities either built into vehicles or in the smart phones consumers carry into vehicles are increasing rapidly along with driver-assist technologies that will ultimately lead to driverless vehicles. Infrastructure providers must figure out what they want to communicate to vehicles operating on their systems and how. Information such as the precise location of work zones and congestion spots will need to be collected and distributed electronically.

At the same time, infrastructure providers need to figure out what information they want to harvest from passing vehicles. Existing smart-phone apps, for example, turn vehicles into data-collection devices for roadway conditions, using information about sudden swerves and bumps to identify roadway hazards and maintenance needs.

Current driverless-vehicle prototypes such as the Google car do not depend on communication among vehicles. Each vehicle is self-contained. There are safety and operational benefits associated with both smarter infrastructure and facilitating communications among vehicles. For example, infrastructure providers might install red-light-warning systems that alert vehicles in the vicinity that a light is turning red and that a vehicle is traveling too fast to stop in time. Vehicles might communicate road-hazard information among themselves on an ad hoc basis so each vehicle is warned of the risk of a collision and can take appropriate evasive action to avoid colliding with the errant vehicle and each other.

Authorities need to respond

Toll authorities are the transportation entities with the strongest incentive to facilitate the transition to driverless-vehicle technology. Such technology will allow them to increase traffic flow and hence revenue on their existing roadways. Freeing customers from the drudgery of driving so they can concentrate on other things allows toll authorities to provide travelers with an improved travel experience that can be priced. Safety improvements mean less revenue loss from accidents that block traffic. Smart-car technology has the potential to replace the current radio-frequency identification-based methods of electronic-toll collection with better approaches.

Infrastructure providers will have to help shape changes to the legal regime that driverless vehicles will require. The legal system will have to adapt liability rules to the fact that human occupants are not in direct control of vehicles. Vehicle and motorist licensing laws will change. Privacy rights (and waivers of such rights) must guide the flow of data among vehicles and infrastructure. Highway authorities and suppliers of driverless vehicles may spar over who controls traffic flows and speeds on highways.

Even if highway authorities adopt a largely passive role, content to lay down concrete and leave responsibility for the rest of highway transportation to others, the shift to driverless vehicles will force them to adjust investment priorities and develop new capabilities. The tax- and toll-paying public won't stand for spending public money on physical expansion of highways when investments supporting driverless-vehicle technology can increase capacity more cost-effectively and lead to a travel experience that is safer and superior from the consumer's perspective.

The land-use changes propelled by driverless-vehicle technology will inevitably affect infrastructure providers. One key challenge arises from the fact that such technology increases the carrying capacity of highways. How do existing arterials and service roads adapt to the increased volume of traffic to and from the highways? Can the capacity-enhancing benefits of driverless vehicles be distributed equally throughout the highway system, or will there be disjunctions that will have to be overcome through design and reconstruction of highways and streets, at both a concrete and electronic level?

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With these challenges come real opportunities for the intensification of residential and commercial development along highway corridors as a result of the higher traffic flows that will result from the deployment of driverless-vehicle technology. This densification will be a source of demand for infrastructure providers.

A possible delinking of buildings and residences from parking lots will result in changes to the built environment. If on-site parking lots shrink or even become obsolete, how will the freed-up land be used? How might "valet" areas be developed near shopping malls and office buildings so people can summon driverless vehicles? Building types in highway corridors will certainly change if driverless-vehicle technology allows much greater density along such corridors.

Just as it was difficult in 1910 to foresee the many infrastructure changes associated with the automobile that would occur over the next few decades, including superhighways, the explosion of suburban development, and even gas stations, it is difficult to predict how the built environment will change as a result of driverless-vehicle technology. What seems quite possible is that the changes will be equally profound.

Infrastructure providers that are innovative and adapt to the likely demand for infrastructure that communicates in ways both active and passive with increasingly smart and ultimately driverless vehicles will thrive. Those providers who have expectations of living on an ever greater volume of highway construction—as opposed to creative highway repurposing—are likely to have those expectations dashed.

Likewise, metropolitan regions that embrace driverless-vehicle technology will get a leg up on those regions whose transportation systems remain stuck in the 20th century. Those innovative regions will be more attractive to the connected persons who make up much of today's creative class. Such technology will free up major blocks of time when people no longer have to pay attention to the pedestrian task of driving. Some of that freed-up time will result in productive work and, at a minimum, enhance the relative quality of life in the region.

More effective use of existing highways will free up capital for other uses and allow more intensive development along those highways, adding to the tax base and local gross domestic product.

Improved highway safety will reduce health-care costs.

The mobility enhancements associated with driverless-vehicle technology will allow more people in a metropolitan area to participate in the labor markets and civic life. These regions will capture a greater share of the new industries that undoubtedly will grow to support driverless-vehicle technology.

Driverless-vehicle technology is being deployed in stages with every new automobile model year and through the concerted efforts of innovators such as Google. As happened a century ago when the automobile was introduced, technological innovation was much faster on the vehicle side than the infrastructure side. However, in coming decades infrastructure providers and highway authorities will face many challenges responding to and enhancing driverless-vehicle technology. These same challenges are really opportunities to help reshape our built environment and transportation system in the 21st century in a very positive way. **TM&E**

Bamonte is general counsel at the North Texas Tollway Authority, Plano, Texas. He can be reached at tbamonte@ntta.org.