TRANSPORTATION RESEARCH
CIRCULAR
Number E-C201 November 2015

Linking the Past to the Future

Lessons from History About Emerging Technology

June 13, 2014
Washington, D.C.

TRANSPORTATION RESEARCH BOARD

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Standing Committee on Transportation History

November 2015

Transportation Research Board
500 Fifth Street, NW
Washington, D.C.
www.TRB.org

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Introduction

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This E-Circular is the result of a collaborative effort during 2014 and 2015 by the TRB Standing Committee on Transportation History and the Intelligent Transportation Systems Joint Program Office (JPO), which is part of the Office of the Assistant Secretary for Research and Technology of the U.S. Department of Transportation. The JPO's mission is to advance the use of intelligent vehicles, intelligent infrastructure, and the creation of an intelligent transportation system (ITS) integrated across all modes of transportation. The federal ITS program supports the overall advancement of ITS through investments in major research initiatives, exploratory studies, and a deployment support program, including technology transfer and training. The JPO coordinates ITS programs across all modal administrations and integrates the national effort to promote the advancement of ITS.

The transportation industry, policymakers, Congress, the media, and members of the public have been exposed to a constant stream of information about technological change in transportation, including realistic and fanciful projects about technological revolutions that are just around the corner. It would be a mistake to anticipate that technological innovation will either solve all our transportation problems or create unmanageable, nightmarish futures. Our field has benefitted from technological change since the invention of the wheel and the sail, and every innovation has produced unintended as well as intended outcomes. The Standing Committee on Transportation History believes that the study of past technological advancements has enormous value for the present and future. We also believe that TRB should be the locus of further efforts to learn from the past so as to influence present policies in service of a better future.

Discussions between members of the Standing Committee on History and JPO Director Kenneth Leonard addressed the fact that progress toward ITS and autonomous vehicles is a social and institutional process as well as a technological one. Understanding the implications of technological change can be enhanced by awareness and understanding of the social and institutional aspects of technological innovation reflected in the adoption over many decades of earlier innovations in transportation. From these early discussions came the development of a day-long workshop that was held June 13, 2014, at the TRB Keck Center in Washington, D.C. Invited participants at the workshop included about 30 people, some of whom are members of the Standing Committee on Transportation History, and others of whom were active participants in the development of past and recent policies and programs related to ITS. The workshop featured a lively exchange and proposals for research, and participants recommended that the History Committee bring the issues addressed before a larger audience by scheduling a session at the TRB 94th Annual Meeting. Because most of the presentations at the workshop and the Annual Meeting session were not previously or subsequently published, it was decided that this E-Circular would make some of the principal ideas available in writing to a wider audience. The JPO remains committed to bringing the lessons of history to bear on the future of ITS and autonomous vehicles, while the History Committee remains committed to addressing the societal implications of technological change in transportation.

In addition to the authors of the presentation summaries, who are identified in the contents, Larrie D. Ferreiro, Jonathan Gifford, Alan Pisarski, and I led the planning of the workshop and the session at the Annual Meeting. The workshop and the Annual Meeting session were encouraged by the JPO, and senior staff member Ken Leonard participated in planning. A copy of the workshop program is included in this E-Circular as an appendix. The Standing Committee on Transportation History thanks Anne Brown, a doctoral student in Urban Planning at the University of California, Los Angeles, for editing the contributions to assure their clarity and consistency in presentation. In addition, special thanks to TRB staff James Bryant and Joanice Johnson for helping to make this E-Circular possible.

The views expressed in the technical papers are those of the individual authors and do not necessarily represent the views of TRB or the National Research Council. The presentation summaries have not been subjected to the formal TRB peer review process.

What Can History Tell Us About the High-Tech Future of Transportation?

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History can enlighten and inform by demonstrating how prior technological innovations fostered rivalries and their resolutions. History can also reveal the successes and limitations of policy in governing technological adoption and adaptation, and highlight how institutions adapted, impeded, or accelerated technological impacts.

The idea that technology drives social change is common. Yet social scientists have long argued that the influence is as much or more in the other direction. Society "constructs" technology at least as much as technology constructs society (*1*).

What is technology? One useful definition is that technology is knowledge about how to combine capital and labor to create value. Society can advance by expanding the labor force, by expanding the capital stock, and by learning how to combine capital and labor in new ways, that is, by advancing technology (*2*).

Technological advances seem omnipresent in today's transportation sector. System users increasingly expect facilities and vehicles to be bundled with information about location, operating conditions, reliability, and performance and delivered to mobile and desktop devices on demand, 24/7.

Self-driving cars are on the horizon, and some features of this future technology are already here. A recent news article reported that auto manufacturers are weighing carefully how to introduce new technological features that users say they want—adaptive cruise control, lane departure warning, and collision avoidance—and, at the same time, preserve the freedom and autonomy that are a hallmark of the automobile (*3*).

Shared-vehicle services like Car2Go and Zipcar and bike sharing are widely available. Ridesharing services like Uber and Lyft are disrupting the taxi and limousine industry. Real-time pricing of parking is available in some cities. And payment innovations are widespread in transit, parking, and toll collection.

How will these technological innovations affect society and how, in turn, will society affect the adoption and use of these technologies? How will users respond to increasingly autonomous vehicles? How will automobile purchasing and use change with the emergence of shared use? What are the implications for land use, the allocation of street space, safety, and mobility for disabled and disadvantaged populations? What public policies need to be considered or reconsidered?

Looking back at technological breakthroughs of the 19th and 20th centuries is instructive. While the rate of technological change in the early 21st century may seem faster than it has ever been, consider the 19th century breakthroughs of the railroad and the telegraph. Those two technologies accelerated the transmission of information, people, and freight by orders of magnitude. Long-distance information transmission shifted from the speed of a Pony Express rider to the speed of light (*4*, *5*).

What lessons can history teach about transportation's high-tech future? First, perhaps, that the social adaptations will be rivalrous. Incumbent industries do not cede their markets without a fight. Elites do not cede their wealth, power, and influence willingly.

A second lesson is that public policy can shape society's response. It can sometimes accelerate or brake adoption and impact. But its ability to dictate processes and outcomes is limited.

And finally, institutions are important. Institutions refer not only to formal organizations, but also to norms and values. Institutions will shape the future of high-tech transportation. These effects will require formal institutions to adapt their workforce development, and their budget and procurement practices. The boundary between public and private may shift as well. Informal institutions such as privacy may shift as well, as we have already seen with social networking services (*6*, *7*).

History can thus enlighten and inform by demonstrating how prior technological innovations fostered rivalries and their resolutions, the successes and limitations of policy in governing technological adoption and adaptation, and how institutions adapted, impeded, or accelerated those impacts.

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Going Faster in the Wrong Direction?
History's Lessons for the Future of Roads and Streets

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Often neglected, past histories of policy successes and failures can offer a wealth of insight that can help guide us during innovative times. However, if we neglect history's lessons, technological innovation may mean going faster in the wrong direction. We should give the compass as much attention as the throttle. We need not be "condemned to repeat" the past if we will only recognize its lessons.

Smarter transportation systems can solve problems, but they also entail risks. To appreciate these risks, we must first recover a historical record that we've substantially neglected. To some, history is no guide to a future transformed by technological innovation. Such commenters fail to find lessons that transcend particular boundaries of technology or setting. Their consequent enthusiasm is a kind of naïveté and history is rich in examples of its costs.

Only the historically naïve see technological innovation simply as science applied impartially to the solution of human problems. Innovation is also a disruptor of status quos, a shifter of balances of power, and a trigger of waves of unintended effects. Too often, autonomous vehicle systems of networked, driverless cars have been presented as a solution to the problems of a transportation system dominated by the conventional automobile. But such optimism is wishful thinking if it repeats past errors in new forms. After all, the transportation system featuring the conventional automobile was sold as the solution to problems, too. Conventional cars were to deliver freedom, but by degrading alternatives they also fostered dependency. Motor highways were sold on grounds of safety, but because they induced risk compensation and diverted travelers from safer modes, the benefits were disappointing. Highways were to relieve congestion, but often exacerbated it by favoring the least spatially efficient mode at the expense of all others. The lesson is to forego eager enthusiasm about transformative transportation innovations, not for a reflexive pessimism, but for an informed prudence.

A transition to networked systems of self-driving cars offers enormous benefits. Its unintended effects would be enormous, too. We cannot know these effects with certainty, but if we're to manage them successfully, we must gauge them with care. In the naïve confidence that the future is another world, hard-earned lessons of history have been neglected.

THE EFFICIENCY PARADOX

As an imperial power in 1865, Britain was helping itself to the resources of the world. Resource depletion was hardly a threat. As a domestic resource that powered the nation's industrial might, however, coal was different. As Britain industrialized, consumption of coal accelerated. Each year, more tonnage was laboriously extracted. Remaining reserves were vast—but with accelerating industrialization, would the coal last (*1*)?

Conventional wisdom took heart in another clear trend: steam engines were growing much more efficient. With technological innovation, new engines yielded more useful work per ton of fuel. As each engine worked more for less coal, total coal consumption would presumably fall, even as industrial production rose.

In 1865 a brilliant mathematician, logician, and economist dashed these hopes. William Stanley Jevons studied steam engines' productivity and the nation's coal consumption. His finding, published as *The Coal Question*, was troubling. It "is wholly a confusion of ideas," Jevons wrote, "to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth" (*2*). The more efficient steam engines became, the more profitable it was to operate them and the more profitable applications they found. Improvements in steam engines accelerated the pace of industrialization and coal consumption would continue to rise.

SIDE EFFECTS

Efficiency gains are desirable, but entail risks. The risks can be managed, but only if duly considered. Today we appear to be at the threshold of a transportation efficiency breakthrough. Self-driving cars, in particular, may help us get much better use out of each car on the road, improving spatial, economic, and energy efficiencies. But the obvious attractions of such efficiency gains conceal threats that are all the more dangerous because they are not so obvious. Justifiable optimism, as opposed to mere wishful thinking, is based upon prudent attention to risks.

What will happen to total vehicle miles of travel if automated vehicles make driving much more efficient? Across 150 years, Jevons cautions us that efficiency gains will induce greater usage—enough, perhaps, to increase total consumption of energy, time, and space. Efficiency gains in the form of faster Internet connection speeds don't diminish the time users spend online; they increase it by making it more rewarding. What are the analogous implications for more efficient driving? Rather than halve commuting time, such efficiencies may double commuting distance, perhaps negating energy savings and making the urban sprawl of today seem quaint by comparison.

Ubiquitous automated driving may displace other modes, even among those who prefer them. The mobile phone did not just make communication more convenient for its early adopters, it also disrupted alternatives. In time, this made the mobile phone a practical necessity for everyone. By the same token, the conventional automobile curtailed walking dramatically. Through its effects on urban form, the choice of many to drive curtailed the choices of many others, who then drove less by choice than by necessity. By rebuilding our landscape for conventional cars, we made walking and bicycling harder for everyone. A world rebuilt again for automated driving systems may make walking and cycling still harder. These modes are second to none for energy efficacy, spatial efficiency, and public health benefits. Automated systems promise mobility to those who can't now drive, but much of the nondriving population is children and youth. Before we head toward a future in which driverless cars further displace walking among children, let's consider: Is this a future we really want?

A FORGOTTEN SUNDAY IN 1926

Analogous innovations of the past offer lessons. One forgotten case is offered here as an example.

At 8:00 a.m. on Sunday, February 7, 1926, Chicago Mayor William E. Dever threw a switch on a central control panel, linking a network of traffic signals in central Chicago through wires, electromechanical relays, and electric clocks. It was in a small way the beginning of intelligent driving systems, in that the Chicago system coordinated vehicles to behave more efficiently.

The system was the product of a coalition of business groups, including the Chicago Association of Commerce, the Chicago Surface Lines, and the Yellow Cab Company, who were seeking a way to keep vehicular traffic moving. With coordinated systems, authorities could time traffic signals in relation to each other, permitting them to let vehicles traveling on a major thoroughfare at a designated speed pass through an unbroken succession of green lights. The system would not work when congestion slowed vehicles below the designated speed, but by increasing a street's vehicular capacity it could prevent such congestion—and with no new road construction. For motorists, the efficiency benefits were clear. While speeders would arrive at the next intersection too soon for the green, drivers maintaining the designated speed would drive through intersections as if there were no cross streets at all.

In these respects, coordinated signal systems offer a fair analogy to driverless cars. Both systems promised to increase vehicular throughput without new lanes or other expensive infrastructure. And signal coordination delivered. *The Chicago Tribune* tested the system on that first Monday, finding that "from the motorist's standpoint, Chicago's new traffic control lights regulating the human tide in loop streets won an instant and unqualified success" (*3*).

But there's more to the analogy. Coordinated traffic signals were not merely an efficiency improvement. Like any other implemented innovation, they shifted balances of power. Most street users in Chicago, before and after coordination of traffic signals, were pedestrians. The common law granted them rights to the street equal to those of other street users. Before signal coordination, Chicagoans exercised these rights freely, though they had to make frequent compromises. Motor vehicles stuck in traffic were nuisances to drivers, but pedestrians learned to negotiate their way between them. At intersections controlled by traffic police, pedestrians usually found their needs served. With signal coordination, traffic on major streets flowed more quickly and steadily, but the lights were less interested in pedestrians' needs than traffic police had been.

To Chicagoans of 1926, streets were for pedestrians as much as for cars. If this defies our notions of common sense, it's because our common sense is shaped by history—including the introduction of coordinated signals. Pedestrians boarded and alighted from streetcars at "safety zones" along streets' centerlines, making access to the street between intersections both an officially condoned practice and a practical necessity. Moreover, signals optimized for motor vehicles often left insufficient time for the slower pedestrians to cross. The message to pedestrians was that they were on their own.

The problem was evident on that first Monday. Observing the traffic, then–police chief Morgan Collins admitted, "The pedestrian is our one big worry" (*3*). By Wednesday, *The Chicago Tribune* reported that "the pedestrian problem became more acute as driver confidence in the control system increased and cars moved faster across the crowded intersections." At some busy intersections, "the walker found life one succession of heart thrills, dodges, and jumps."

Many pedestrians who tried to comply with the signals found the lights changing before they could get across. “At almost any moment in the afternoon and early evening,” *Tribune* reported, “a score or more persons could be seen stranded in the middle of these intersections between two steady lines of vehicles or huddled in the streetcar safety zones awaiting their chance to skip to safety on the sidewalk” (*4*). Chicago pedestrians resented the system and defied it when they could. The better traffic flow also attracted more drivers to the Loop district—so many more that in 1928 the city resorted to a daytime parking ban.

Chicago in 1926 was a different world, but the lessons of its pioneering coordinated signals matter today. Its efficiency gains did not reduce traffic, for reasons Jevons had explained 60 years earlier. The lesson is pertinent in assessments of the driverless car. The Chicago case also reminds us that social groups do not benefit equally from innovations and some may lose. Though pedestrians were the majority, they were not represented in the development of the plan, and the signals did not sufficiently take their needs into account. Pedestrians’ consequent resentment and evasion of the system did not work to its advantage. Similarly, not all will benefit from driverless cars equally. If the solution is to make everyone—including pedestrians and bicyclists—into users of driverless cars, we may be transforming a means of transportation to an end in itself.

Perhaps the most important lesson from the Chicago case is that we will not escape our biases without strenuous effort and deliberate inclusion of others’ perspectives. Impartiality will take not an elusive objectivity but multiple subjectivities deliberately and fairly gathered. *The Chicago Tribune* astutely qualified its assessment of the coordinated signal system—its success was “from the motorist’s standpoint.” How extraordinary that in 2015 this qualification is so rare in engineering analyses that consider the motorist’s viewpoint almost exclusively. Transportation planners Eric Dumbaugh, Jeffrey Tumlin, and Wesley Marshall have examined the assumptions that turn empirical data into designs that preferentially favor driving as the normal mode of mobility—a bias with a powerful self-fulfilling effect (*5*). Recently, journalist Eric Jaffe and planner David King noted that the pedestrian’s perspective is often absent in models of driverless car systems. Jaffe notes “it would be a huge mistake for cities to undo all the progress being made on human-scale street design just to accommodate a perfect algorithm of car movement” (*6*). The developers of the 1926 Chicago system made this mistake. Because of our inattention to history, we are making the same error again today.

The Chicago signal story is just one of many examples of hard-learned lessons that have been forgotten. The example is offered because it represents the vast reserve of neglected cases that together offer us the wisdom of experience, if we will only find and study them. In the neglect of their lessons, technological innovation may mean going faster in the wrong direction. We should give the compass as much attention as the throttle. We need not be “condemned to repeat” the past if we will only recognize its lessons.

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Getting Behind the Wheel
Society and the Adoption of the Automobile

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Social, legal, political and economic contexts determine whether technology and innovation is adopted quickly, slowly, or never at all. The importance of each of these contexts is illustrated by the widespread adoption of the automobile in the United States. Society's embrace and a constellation of social, political, legal, engineering and economic factors were necessary in order to turn a toy for the rich into a ubiquitous mode of travel. Enthusiasts for autonomous vehicles take note—social acceptance; accommodating political, legal and regulatory frameworks; and feasible economics will all be necessary to put computers in the driver's seat.

Technology might be created by a lone inventor-tinkerer in his garage, but the adoption of that technology is a societywide process. Depending on the social, legal, political and economic contexts, technology and innovation may be adopted quickly, slowly, or never at all.

The electric streetcar is a case of the former: it was first tested in the United States in Richmond, Virginia, in 1888, and by 1904, 94% of streetcars ran on electricity. The streetcar quickly gained traction in part due to the fact that the horsecar had acclimated the public to the service. An example of a failed technology is the steam auto, which never caught on for reasons more social and political than technological. As for a technology that was adopted slowly, the internal combustion auto was first introduced in the 1890s, but was not truly embraced as a mass market form of utilitarian transportation until the 1920s. Moreover, mass motorization in Europe lagged behind that of the United States by decades.

Certainly, many of the developments that led to the eventual adoption of the internal combustion auto were technological in nature. Foremost among these, of course, were Ford's introduction of the durable, light, and easy-to-maintain Model T, and its deployment of the moving assembly line a few years later, which caused the time to produce the car, and thus its price, to plummet. A host of innovations, especially the full enclosure of the vehicles, the electric starter, and electric lights were crucial in turning the auto from a recreational pastime for hobbyists into a means of everyday travel in the 1920s.

However, political, social, legal, and economic developments were as crucial as technological ones in putting Americans behind the wheel. The demise of the steam auto is a case in point. Steam autos were feasible at least a decade before internal combustion engines, but never mustered societal enthusiasm; they were associated with steam trains, which were extremely unpopular in cities thanks to noise, soot, fear of accidents, and boiler explosions. Steam trains were banned from many cities.

Four primary political, social, legal, and economic developments aided the widespread adoption of the internal combustion auto. First, regulations against privately operated vehicles began to crumble just as the internal combustion auto was becoming feasible. The path was paved by bicyclists. Like trains, bicycles were also unpopular among much of the general public, and in some places municipalities banned bikes. However, legal precedents in the 1880s and early 1890s established that these bans were illegal and that cities could not regulate which vehicles were permitted on their streets. This would facilitate the adoption of the auto, which was also unpopular with much of the public in its early years.

Bicyclists also helped lead the way for improved road surfaces. Previously, road surfaces in the United States had not been conducive to the adoption of the auto. A majority of city streets in the United States were unpaved even through 1890, and the paving surfaces that did exist, such as cobblestones, did not offer smooth rides. Again, bicyclists paved the way here, forming the "Good Roads Movement" which would be enthusiastically joined by motorists. The answer to their lobbying appeared in the 1890s, with the development and deployment of asphalt and portland cement concrete paving. This was in part a technological development, but also a political one: municipalities began assuming control over road funding in place of the abutters living on the street, who, thanks to a desire to save money and discourage through traffic, had had little incentive to invest in quality pavements. The gradual assumption of control of paving by municipalities took place because of a desire to promote the movement of traffic, but also because a paving surface that was easy to keep clean was needed. Ultimately, it was facilitated by the demise of the "ward boss" system in favor of mayoral control and the replacement of the patronage system with the civil service and commissions guided by experts. In 1890, roughly 8% of city streets had asphalt, concrete, or brick pavement, a figure which rose to about 15% in 1900, 22% in 1910, and 47% in 1920. However, these aggregate figures are somewhat misleading since the main traffic thoroughfares were the first to get the new paving surfaces. Other political developments, such as the professionalization of street cleaning and maintenance, also rendered roads more suitable for automobile traffic.

A third major development, spurred by real estate economics, was the creation of a new type of roadway. Driven by developers who had seen that property with access to parks increased in value, the "parkway" was designed to furnish park access to properties that were not immediately adjacent to greenspace. Originally meant as aesthetically pleasing recreational facilities that served well-heeled residents out for weekend jaunts, parkways' limited access and grade separation (the roads typically had few at-grade intersections) made them desirable facilities for auto travelers. Developed in large part by New York's Robert Moses, the parkway was eventually to evolve into the modern freeway.

Fourth, order was brought to the streets, in large part thanks to William Phelps Eno. Eno wrote the first traffic code in the United States (for New York in 1903) in response not to autos, which were still something of a curiosity, but to horse-drawn traffic. He invented or popularized the stop sign, yield sign, pedestrian crosswalk, traffic circle, one-way street, taxi stand, and pedestrian safety island. These developments were key to segregating incompatible forms of traffic (e.g., they kept pedestrians out of the street) and facilitating traffic flow; these rules of the road were essential in allowing automobiles to operate.

Other societal developments shifted public opinion in the auto's favor. The bicycle and the streetcar had helped the public become accustomed to high-speed vehicles in cities. Highly publicized auto endurance road races in the 1890s helped stoke interest in the new technology. There was widespread dissatisfaction with the urban horse, and the many safety and environmental problems it caused, making a replacement highly desirable. There was also frustration with streetcar service due to crowded vehicles, restrictive schedules, unreliable service, and shoddy maintenance. Combined, these reasons caused many observers to enthusiastically hail the auto as a potential cure for environmental, mobility, and economic problems by the late 1890s.

The contrast between the adoption of the auto in the United States and Europe is instructive. If the introduction of the auto was purely a question of technology, Europe, where most of the technological innovations were developed, likely would have motorized first. However, due to social and economic factors, it lagged behind the United States. Europe had a fragmented market with high tariffs between countries that thwarted the exploitation of economies of scale, high taxes on fuel, little petroleum production, and relatively low consumer purchasing power (in part due to the economic disruption caused by World War I). All of this meant that society did not adopt the auto as rapidly as across the Atlantic.

In sum, the auto would not have been adopted without society's embrace. A constellation of social, political, legal, engineering, and economic factors needed to cohere in order to turn a toy for the rich into a ubiquitous mode of travel. Enthusiasts for autonomous vehicles take note—social acceptance; accommodating political, legal, and regulatory frameworks; and feasible economics will all be necessary to put computers in the driver's seat.

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Decision Framework for Assessing Technological Change in Transportation and Its Impacts on Society

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Transportation technologies, when combined with other features of their contemporary context, produced unexpected changes—often more significant than their intended consequences. While not a recipe for forecasting or specific scenario development, the lessons of history suggest certain rules can be set forth as a point of departure for structured thinking about the societal impacts of currently evolving technologies. A framework described provides a useful starting point for identifying areas of societal impacts of vehicle automation in terms of topics that are both useful and researchable.

There is reason to believe that the evolution of vehicle automation represents the kind of disruptive transportation technology that—depending on the future context in which it evolves—will have long-range and large-scale implications beyond its intended direct impacts on improving safety and mobility. A considerable literature describes direct impacts of automated and connected-vehicle technology applications on crash avoidance, congestion reduction, mobility enhancement, and reduced environmental impacts—showing significant direct benefits. However, cautionary lessons from the history of transportation indicate that the impact of technology synergizes in complex and often unpredictable ways with its social, business, and institutional context. These synergies produce a mix of unintended consequences—good and bad, large and small—and with unpredictable timing and incidence.

HISTORICAL LESSONS

The Standing Committee on Transportation History discussed several examples of how specific transportation technologies evolved, but when combined with other features of their contemporary context, produced unexpected changes—often more significant than their intended consequences. Examples of major changes examples include the replacement of the horse by the automobile and truck and the development of the Interstate Highway System. Another example presented focuses on the mid-19th century shift from sail to steam power and its impacts on foreign trade. While the speed and reliability benefits of steam propulsion over sail might be expected, the historical record suggests other factors were equally—if not more—important than mode shift to trading partners' comparative advantage, modal competiveness, key players, and level of profitability. These factors included changes in currency and barter practice, business models, banking facilities, corporate organization, and telegraphic communications. Together these factors determined the rate and nature of the impacts of steamships, either diluting or accelerating them in unexpected ways depending on context. These examples suggest the complexity of the synergistic impacts of simultaneous changes in transportation technology and its context (*1*).

Strategic thinking about the implications of vehicle automation in its likely future context is highly speculative; however, historical case studies yield valuable lessons about how to look at technology impacts in terms of direct and indirect effects; lag times; evolution, disruption, and displacement; economic, social, and environmental considerations; unexpected synergies; and conflicts among technologies. While not a recipe for forecasting or specific scenario development, the lessons of history suggest certain rules can be set forth as a point of departure for structured thinking about the societal impacts of currently evolving technologies.

FRAMEWORK FOR THINKING ABOUT FUTURE IMPACTS OF VEHICLE AUTOMATION

It is useful to have a framework within which to structure key issues in thinking about the potential longer-term social, environmental, and economic impacts of the technologies associated with automated–connected vehicles. One approach is to examine is to structure thinking in terms of the technologies, how they are combined to provide needed functions, the direct immediate impacts of deployment, and the long-range implications related to broader societal implications for policy-making purposes.

Relevant lessons of history include—but surely are more numerous than—the following:

Technology Platforms

The dictionary definition of technology ("the ways in which society provides itself with material and goods") highlights that automation and connection are not related to single technologies, but are combined and configured into "platforms." Platforms are the unit of direct technology impact. For example, navigation and traffic probe information may or may not be combined into a service that substantially improves traffic level of service.

External Dependency

A structured examination of the future must account for technology contributions from outside the transportation sector, which today would include advances in information technology, materials, systems, and communications. Furthermore, behavior and institutions may be key to future vehicle automation, such as human factors and behavior; regulation and standards; infrastructure; institutions, regulations, and standards; and business models. The synergies of the interplay between vehicle and information systems and these other dimensions will determine the type and level of impact of the technologies. Institutional context—especially public agency capacity for innovation—is likely to be a major pacing factor (*2*). For example, new forms of public–private partnership and consumer acceptance are likely to evolve, affecting how, when, and where the safety and performance impacts of automation and connection occur.

Direct Versus Indirect Impacts

The direct impacts of vehicle automation on safety, mobility, costs, physical impacts, emissions, etc. are predictable in direction if not in extent or pace. However, potential indirect impacts—social, environmental, economic and institutional—while more speculative, may be just or more significant from an overall societal perspective. For example, what are the likely implications of decreased fatality rates (a direct impact of automation) for the health, insurance, and law enforcement industries (revenues, employment)? The mechanisms of interplay between direct and indirect impacts will play a key role in determining the effects of automation.

Disruptive Versus Radical Innovation

Disruptive technologies build incremental performance changes on existing technologies and products consistent with business as usual (power steering). Contrastingly, radical technologies introduce replacement products with steep changes in performance and broad impacts (automated braking). Old and new systems (such as roadside traffic signs and in-vehicle traffic advisories) may continue to coexist over long time periods. However, at some point, the disruptive can segue into radical territory and render the older approaches irrelevant.

Time Frame

Given the likely 30- to 40-year time frame for significant automated vehicle market penetration and slow rate of institutional capacity improvement in the vehicle–highway transportation sector, the initial platforms, system configurations, and services may well be modified or replaced before significant market penetration of the currently available systems. These alternative technologies may yield very different future cost, service, and related impact configurations than are currently forecast.

CHAIN OF IMPACTS

The first row from Table 1 illustrates an initial "accounting framework" progressing from consideration of specific technology platforms to the presumed direct impacts and the likely longer-term societal implications. The example suggests that technology impacts are shaped by human factors, institutional arrangements, and business models that combine with technology to produce new products and services, and to eliminate others.

RESEARCH

The framework described provides a useful starting point for identifying areas of societal impacts of vehicle automation in terms of topics that are both useful and researchable. In addition, the concept of technologies, platforms, direct impacts, and indirect influences as detailed in Table 1 may be useful to help structure an approach to future scenario building that can capture the full range of more or less likely outcomes. The lessons of history suggest that recognizing the synergy among such dimensions has been at the core of how technologies have produced their principle societal impacts.

TABLE 1 Potential Impact of New Technologies on Highway Transportation: Examples from Operational Support from Automated Vehicle–Connected Vehicle Technologies

Technology-Based Application Platforms	
• In-vehicle info (traffic sign warnings) • Preemptive functions (collision avoidance) • Driver support functions (cruise control navigation) • Assurance services (breakdown/crash) • Car sharing and ride-sharing apps • Advanced Transportation Management Centers	• Driver training • Eco-driving applications • Security/privacy protection • New business models, public–private partnerships
Direct Impacts	
• Increased vehicle density and highway capacity • Improved routing • Speed harmonization (higher speeds) • Driver assist in crashes, navigation • Reduction in congestion • Improved travel reliability • Reduced excess circulation (central business district parking) • Improved parking supply efficiency	• Truck platooning • Automated merging • Safe operations of large trucks • Hands off vehicle operations • Reduced law infraction • Reduced incident clearance times • Viable car-sharing/ride-sharing business models • Reduction in fixed costs of vehicle ownership • Reduced vehicle emissions
Social, Environmental, Economic Implications	
• Reduced freight delivery costs • Increased vehicle miles traveled • Reduced Travel time for given trips (esp. rural/intercity) • Reduced space demand for parking (and off-site potential) • Increased compatibility of vehicle–bike–pedestrian • Improved vehicle maintenance levels • Ability for drivers to make alternative (productive?) use of time • Reduction in vehicle ownership • Reduction in car market (industry impacts) • Reduction in parking income • Reduction in taxi/transit driver jobs	• Reduction in need for law enforcement • Reduction in insurance/health costs (industry impacts) • Reduction in and health costs (industry impacts • Increased highway capacity (ops, lane widths) • Congestion managed and reliable • Reduced need for roadway expansion • Ability to focus transit on high density corridors • Reduced demand for transit (from transit dependents) • Encouragement of mega-regions • New urban design options re accommodation of vehicles

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Uneven Acceptance of Technology for Traffic Operations

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Transportation technology and practices sometimes remain frozen in place and time. If we are to accelerate and improve our service to the public, it is important to understand the reasons for these uneven results. Reviewing a few well-known technological successes and failures helps to illustrate how different technologies flourished or faltered. These examples point to the need for improved public education of modern technology's potential. This can best be accomplished through improved performance measurement that produces data to quantify the successful implementation of advanced technologies. Without reliable accounting of successes and failures, the public will never develop an understanding of what is possible.

The past century has seen an explosion of technological innovation led not only by the information technology (IT) industry, but other sectors including material science, medicine, telecommunications, and many others. The transportation community has both taken advantage of these advances and made innovations of its own. Unfortunately, there are a number of other areas in which transportation technology and practices remain frozen in place, using approaches that have been in in existence since the 1960s. If we are to accelerate and improve our service to the public, it is important to understand the reasons for these uneven results.

To begin with, it must be recognized that the transportation community is not a homogenous industry dominated by a few big companies, as is the case with the IT industry. The transportation community is made up of 50 state departments of transportation, as well as many other entities, including metropolitan planning organizations and city departments of public works. The picture is further complicated by the numerous federal agencies and associations that provide additional guidance and regulation. Changing the technology paradigm within this large complex community is analogous to changing the course of an ocean liner. It is a slow process that requires recognition of available technologies, appreciation of their benefits, and identification of funding needed for their implementation. In some cases, the adoption of a new technology requires its acceptance by a skeptical and litigious public as well as labor unions that might be affected by its use. There is often an incentive to continue with business-as-usual rather than assume the risks and extra effort associated with doing things differently.

While a comprehensive analysis of the adoption of entire range of technological progress is beyond the scope of this paper, it is instructive to review of a few well-known technological successes and failures.

One of the most obvious successes has been the toll industry's adoption of electronic payment systems. Examples including E-ZPass in the northeast, SunPass in Florida, TxTAG in Texas, owe their success to better customer service and reduced toll collection costs. There are more than 20 other mostly unique and incompatible systems. This example illustrates both the successes associated with adopting new technology as well as the challenges of agency independence, which may limit system interoperability. In spite of their lack of compatibility, electronic payment systems have been universally considered a success because they provide improved customer service and reduce the operating costs of toll collection.

A second success story has quite a different background. This success is related to the display of travel times on variable message signs (VMS). These displays are appreciated by travelers because of their value in helping them deal with unpredictable travel times. In contrast with electronic payment systems, participating agencies do not realize any financial benefits from VMS implementation. However, the cost of adding travel times to signs is modest as relatively inexpensive travel time data is widely available from the private sector. The rapid acceptance of this technology is due to a number of factors: (1) the public generally likes it; (2) it can be implemented at a modest cost; and (3) the FHWA actively encourages its implementation. Clearly agencies perceived this as a win-win situation.

There are equally compelling stories associated with technologies that have not been generally accepted. Adaptive signal control, in which traffic signals automatically adjust their timing in response to measured changes in traffic flow, has existed for more than 25 years. It is routinely implemented internationally by countries on every continent. Yet it has only been implemented by approximately 10% of the U.S. agencies with signal operation responsibilities. The stated reasons for not adopting adaptive signal control include cost, increased staff, system complexity, and the absence of a compelling case for its effectiveness. Adaptive control provides the greatest benefits during unusual traffic conditions, such as unpredictable traffic-generating incidents. Yet operational improvements are typically measured during predictable traffic conditions in order to compare system performance under similar sets of conditions. As a result, adaptive traffic signal systems rarely demonstrate the performance improvements of which they are capable. This fact, combined with the additional cost of these systems, discourages their implementation by under-funded and under-staffed agencies.

Ramp metering is a similar technology with proven benefits whose adoption has been very slow. While accurate data is unavailable for the number of U.S. freeway ramps with metering, it is likely that the implementation of this 25-year-old strategy has been even slower than that of adaptive signal control. Reasons for ramp metering’s slow acceptance are similar to that of signal control. In addition, ramp metering often faces added public opposition from motorists whose delays on entrance ramps are increased. Agencies are often reluctant to make the effort to overcome this resistance without the active support from its beneficiaries.

In the case of both ramp metering and adaptive signal control, the lack of public support has allowed agencies to defer their implementation. The absence of this support is, in part, due to the failure of the transportation community to educate their customers regarding “what is possible.” The public believes that we are mired in congestion without any hope for a reprieve. Many believe that poorly timed traffic signals and clogged freeways are an inevitable curse of the 21st century.

This brief overview of technological winners and losers supports the thesis of a diverse, risk-averse, and underfunded community of practice. It also points to the need for improved public education of modern technology’s potential. This can best be accomplished through improved performance measurement that produces data to quantify the successful implementation of advanced technologies. Without reliable accounting of successes and failures, the public will never develop an understanding of what is possible.

Turning Failure in Research into Success
The Intermediate Capacity Transit System Story

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Governments often finance transportation innovation, which is viewed as "wasteful" by critics. Government funding, however, has generated great advances in transit design and technology—just not always in the product or manner that was requested by the funders. In many cases, private corporations harness government innovations to fulfill a different purpose than for which they were originally intended. Therefore, far from wasteful, government failure may well be the road to commercial success.

After World War II, the transit industry was in dramatic decline. Outdated equipment, rising costs that exceeded revenue, and the inability to serve new and expanding suburbs caused many networks to declare bankruptcy or to be municipalized. This situation led transit industry leaders to look towards modernization to reduce operating costs. Among the earliest actions taken by most networks was replacing the aging streetcars with new bus fleets. More drastic approaches included reducing frequency of service, abandoning lines, and in some cases, shutting down complete networks. The quest for improved transit finance also led to a wave of subway construction in the United States and Canada. Cleveland, Ohio, and Toronto, and later, Montreal, Canada, built subway networks that would operate in a hub-and-spoke configuration, in the hope of more modest operating costs. Other cities such as Philadelphia and Chicago expanded their networks with the same principles. While seemingly counterintuitive, this was a logical step for most cities; while bus networks ran deficits, subways were able to absorb a much higher level of expenditure, sometimes even making a profit.

In the pursuit of lower operating costs, subway networks adopted new technologies from advances made during the World War II. New and fast modern rail vehicles incorporated advances in propulsion systems, communications, automation, and navigation. Standardized parts and modern vacuum tubes led to systems that were also cheaper to operate and maintain than were older models.

During the 1960s and 1970s governments around the world invested massively in mass transit research. In the United States, the great society ideals pushed the federal government to get involved in mass transit development. Projects emerged under President Johnson and continued during the Nixon Administration. Particular projects included Washington, D.C.'s, subway, as well as San Francisco's Bay Area Rapid Transit system. During this same time, the U.S. standard light rail vehicle (LRV) was also developed as a new generation of LRV. Additional U.S. advancements included a state-of-the-art car project, which developed a new generation of subway railcar, and the Transbus project, which created the General Motors RTS bus. The provincial government of Ontario also funded research into the development of new buses, streetcars, subway cars, commuter rail cars, and personal rapid transit (PRT). The West German government invested in various transit technology projects, pursuing research, network expansion, and magnetic levitation (maglev) trains. The French government funded the development of high-speed rail (TGV) rolling stock, the first generation of new LRV, the Tramway Standard Français (TSF) and the PRT system ARAMIS.

Over time, many of these projects became mired in controversy. There were cost overruns, projects that were unable to live up to expectations, and products that did not respond to the needs of the transit industry. Finally, in some cases, governments simply lacked the available funds to proceed past the research phase into implementation.

One of these 1960s- and 1970s-era projects was the development of a medium-capacity driverless subway technological platform. This technology survived several failures, ownership changes, and rebranding to become one of the most popular Bombardier Transportation train control systems and is used globally today.

In 1971, the West German government funded a 5-year grant to Standard Electrik Lorenz to develop an urban automatic maglev transit system that would offer a level of service comparable to PRT but with a higher capacity (18 passengers per car instead of four). From this grant, the Intermediate Capacity Transit System (ICTS) was born. The "brain" of this automated transit system is the SelTrac, which effectively permits driverless subway operations. This technological advance was crucial in improving transit in the suburbs where low development density patterns could not fill the high capacity of traditional subway cars, but patrons still desired high-frequency service. The solution was a small vehicle with a high frequency. In order to keep costs low, its operations also needed to be automated. In 1973, the Government of Ontario, through its Crown Corporation OTDC, purchased the rights to market the product in North America. However, major technological hurdles identified in 1974 caused the West German government to cancel funding for the project.

Despite canceled West German funding, the Urban Transportation Development Corporation (UTDC) (formerly OTDC) took over the project and continued developing the technology. Over time, conventional steel wheels replaced the levitating trains, and the vehicle size was increased yet again. The first three of these projects were built in suburban Toronto (Scarborough); Detroit, Michigan; and Vancouver. Despite UTDC success with other transit ventures—its Orion Buses, the Canadian LRV streetcars, subway cars, and bi-level commuter railcars—they were unable to complete any sell the ICTS to additional cities. In this vein, there was an attempt to adapt the ICTS guideways, signalling, and vehicles, for suburban operations with longer railcars, conventional propulsion, and a pantograph to collect power. However, this new research project was canceled following the abandonment of the proposed project using this technology—GO-URBAN—in suburban Toronto in 1985.

UTDC was privatized in the 1980s, and in 1986, the rail transit division was sold to Montreal-based major engineering firm Lavalin. Lavalin went bankrupt before being able to sell the technology and Bombardier bought the rail transit division in 1991. The platform was renamed advanced rapid transit. It improved with further technological advancements and was later sold to several cities around the world including New York, Beijing, and Kuala Lumpur. Today, the system is branded as Innovia and continues to be sold on the global market and as an important component of Bombardier's product line.

The SelTrac was purchased by Alcatel when UTDC was split up between rolling stock and signaling. It is now marketed by Thales and is one of the most popular automated train operation systems in the world, used in cities such as Beijing, Detroit, Dubai, London, New York, Paris, Shanghai, Toronto, and Vancouver.

When projects are driven by public policies and not market demand, projects can fail. The technological goals may be out of reach or the market might not want your product. However, one of the beautiful things about capitalism is the ingenuity of the private corporation. Private corporations can often salvage innovations and market them for a profit. They do this by offering what the market wants. Although opponents of government-funded research may claim that West German government "wasted" dollars on ICTS, the platform has become a worldwide success. The same can be said about the French TGV and TSF, which have become the Citadis platform, and have become the backbone of the Alstom product line of high-speed train sets and LRVs. Government funding has generated great advances in transit design and technology, but just not always in the product or manner that was requested by the funders. Government failure may well be the road (or in this case rail) to commercial success.

RESOURCES

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Birth and Development of Intelligent Transportation Systems in France

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The evolution of ITS in France began in the 1950s and 1960s, has drawn on developments in technology, and been influenced by operational requirements related to frequency needs, safety assessment methods and certification, human factors, and organizational issues. French ITS continues to be marked by innovation and international collaboration, although there often is a long period of time between invention and innovation uptake.

Intelligent transportation systems (ITS) entered the field of transportation in France soon after World War II and followed the various information and communications technology (ICT) and command, control, communications, computers, and intelligence technologies that occurred in France as well as elsewhere.

The evolution of ITS in France began in the 1950s and 1960s, with the use of "cybernetics" and "operational research." These technologies emerged first with respect to all modes' traffic management and transportation operations, and later with the first attempt to automate a rail locomotive. After the uptake of "flying by wire" concepts by those interested in aeronautics in the 1970s and 1980s, three main automated transit projects (automated people movers or personal rapid transit) were developed for Lille (VAL), Lyon (MAGGALY), and Paris (ARAMIS), the last of which is not in operation. All these projects drew directly upon developments in technology and were also influenced by operational requirements related to frequency needs, safety assessment methods and certification, human factors, and organizational issues.

In the 1980s transportation projects relied on the new concept of "telematics," which was supported by national, intergovernmental, and European research and innovation. Programs that complemented advances in engines and propulsion systems included three major, and historically significant, road-automotive ITS projects: PROMETHEUS (automation and cooperation), CARMINAT (information), and DRIVE (road telematics).

As these projects advanced elements of the program, ITS concepts appeared in public discussions and events, including the First World ITS Congress in Paris in 1994. These events addressed ICT specifically applied to transportation systems. An important milestone was the participation of a French delegation to the 1997 San Diego Demo, which included TV journalists and reinforced the continued development of a good Franco–Californian relationship in the following international seminar on automation. This collaboration had more than symbolic outcomes; the "La Route Automatisée" concept development through the French SCOREF program, raised the question of levels of automation and allowed French stakeholders to provide important inputs at European and international levels.

France invested in the full innovation cycle, including test beds, pilots, field operational tests, innovation incubators and competitiveness clusters, but also, because of their importance, on other critical scientific issues such as acceptance and human factors and human machine interface issues. These efforts were supported by the still-existing HUMANIST Network of Excellence (NOE); road cooperative traffic management (ITS, CO2); through the NEARCTIS NOE with associated members from the United States, Japan, and Australia or the transportation part of the HYCON2 NOE-complex system; the robot sciences (cyber cars) or Internet sciences (IPV6); or micro- and nanotechnologies.

At every stage of ITS development, and even before the appearance of the ITS concept itself, there have been new developments in hardware, software and "orgware," pushed and pulled by knowledge of the transportation and ICT industries and their scientific communities. This has been driven by assessment, benchmarking, and cooperation at the European and broader international levels. Focus in the development of these technologies has often been on reliability, safety and security, and affordability. Also important have been market acceptance, human factors and human–machine interface, as well spectrum allocation and reservation

There has often been a long period of time between invention and innovation uptake. It took 15 years of focused research to transform the aeronautics "flying by wire" concept into an automated underground uptake; it has been the same from CARMINAT to the full operation of RDS-TMC, or for many functionalities coming from PROMETHEUS.

Conclusion

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Consultant

Technological advances are making intelligent vehicles, smart highways, connected vehicles, and autonomous vehicles objects of everyday conversation. New features and services are already available in the current market and others are discussed widely enough that they are familiar to most adults in every developed country. Dynamic crash avoidance, advanced forms of cruise control, and navigational guidance systems are common in vehicles or available on smart phones. New carsharing and ridesharing services are being brought to market every month. Technology and services providers (original equipment manufacturers and others like Google) are predicting availability of full vehicle automation in selected contexts in the 10- to 20-year time frame. The U.S. Department of Transportation (DOT) has a pending regulation regarding onboard technology that would have a major impact both on industry and consequent deployment of technologies. Several states have enacted legislation-setting standards related to the movement of driverless vehicles on state highways. U.S. DOT, TRB, research, and industry entities are conducting studies regarding implementation and its potential costs and benefits, as best they can be identified in the short run.

The experts who participated in the 1-day History Committee workshop and the additional session at the TRB 93rd Annual Meeting in 2014 recognize both the desirability and inevitability of coming changes and urge the transportation policy and corporate communities to address the many social, behavioral, and institutional changes that will arise in response to these technological trends. By studying the history of past innovations, we know that the societal impacts will likely be even more significant in shaping the future than the technological shifts that cause them. We have also learned that society is best served by anticipating and shaping our institutions so that they lead and form the technological changes that are already well underway. Among many research challenges that can help us move towards accommodating and shaping technological change, we offer a small menu possibilities.

The Standing Committee on Research (SCOR) of AASHTO, in seeking proposals for new projects to be developed under the NCHRP in 2017, acknowledged that technological change and innovation is one of the most important areas for future transportation research. This recognition is reflected by the following statement in their call for proposals:

> Transformational, or "disruptive"[1] technologies, are those that can be expected to completely displace the status quo, forever changing the way we live and work. Common examples include the internet, the personal computer, email, and the smart phone. The development of the internal combustion engine is an example of a disruptive technology in the transportation sector.
>
> More current examples of transformational technologies in transportation include connected and automated vehicles, bicycle sharing in urban centers, car sharing (e.g., Car2Go and Zipcar), on-demand shared ride services (such as Uber and Lyft), hybrid and other alternative-fueled vehicles, drones, e-retailing, and 3D printing. All of these are

> facilitated and further complicated by the "Internet of Things"—where systems are connected through embedded sensors and transmitters. The acquisition of real-time data on the infrastructure, vehicles, drivers, and goods will provide unprecedented opportunities to monitor the performance of our transportation systems.
>
> Each of these technologies is the subject of a good deal of research, but collectively they will change the nature and role of the future Department of Transportation. Transformational technologies will impact the way we plan, build, operate, and maintain our transportation systems. DOTs must prepare for an uncertain future and build a workforce with considerably different skill sets. (*1*)

It would be useful to incorporate into research on disruptive technology in transportation insights and lessons from the long history of transportation technology. Among the research issues that were mentioned at the workshop and annual meeting session and that are the subject of this E-Circular, the following were specifically enumerated by members of the History Committee as particularly amenable to increased understanding through historical analysis:

1. Some transportation technology innovations that are wholly private (autonomous) must operate on systems requiring private vehicle–public infrastructure interaction (essentially public–private partnerships). How can we simultaneously advance private technological innovations and the social and physical systems needed to maximize and control their performance?
2. How shall society address the need for and level—extensive or modest—of public regulation (licensing, rates, standardization, liability, security) at the federal level versus state levels, as well as the effects of regulation on customer acceptance, market penetration, costs, and other public interest matters? What can be learned from previous innovations and transitions?
3. What might be the payoff in terms of accelerating societal benefits via direct government support of increased adoption of new private-sector technology through establishment of supported or preferential deployment settings, pilots, and subsidies?
4. Are there potential synergies between vehicle technology and business models capitalizing on related technology to offer other new products and services with substantial independent societal impacts?
5. What are the likely influences on market penetration of new transportation technology including basic fleet turnover rates, customer acceptance, costs of new technology, and OEM versus aftermarket systems?
6. What are the likely future relationships among short-term direct impacts on safety, delay, driver convenience, and longer-term implications such as mobility, equity, goods movement, highway geometrics and pavement design, environment, land use, and economic development, etc.?
7. What is the likelihood that government-chosen technology (as in communications) will be overtaken by improved technologies at various time scales and associated costs and opportunity costs?
8. How shall we address and assess the importance of global cooperation and development of international standards related to technology development?
9. What will be the demands on transportation agencies (at all levels of government) for special capabilities associated with capitalizing on new technologies—including new forms of public–private partnerships?

10. Can we anticipate changes in personal travel behavior and household and business location choices that will result from some of the most widely forecast technological changes in transportation and information technologies?

NOTE

1. The term *disruptive technologies* was coined by Harvard Business School professor Clayton Christensen in 1997.

REFERENCES

1. American Association of State and Highway Transportation Officials Standing Committee on Research. Emphasis Areas for FY2017 National Cooperative Highway Research Program.

APPENDIX

Workshop Agenda

Friday, June 13, 2014

LINKING THE HISTORY AND FUTURE OF INTELLIGENT TRANSPORTATION SYSTEMS
The Keck Center, 500 Fifth Street NW, Washington, D.C.

An invitational participatory workshop jointly presented by the Intelligent Transportation Systems Joint Program Office (JPO) of the U.S. Department of Transportation and the History Committee of the Transportation Research Board. Dress will be business casual.

9:00 a.m. **Opening Session**

Brief welcome from Kenneth Leonard, representing JPO, and Martin Wachs, representing the History Committee. The origins and purposes of the workshop and expected outcomes.

Keynote Address by Professor Peter Norton, Department of Engineering and Society, University of Virginia. *Whose Intelligence: History and Future of Intelligent Transportation Design.*

Eric Morris, Assistant Professor of Urban Planning, Clemson University. *Getting Behind the Wheel: Society and the Adoption of the Automobile.*

The presentations will be followed by group discussion.

10:15 a.m. **Origins and Purposes of the Joint Program Office and its Present and Future Missions**

Christine Johnson, Founding Director of the JPO. *Intelligent Vehicle Highway Systems: The Early Years.*

Kenneth Leonard, Director of the JPO, will follow with comments on Dr. Johnson's observations and briefly address the current status of the JPO, its objectives and programs.

The two talks will be followed by group discussion.

11: 15 a.m. **Brief Case Studies**

Pierre Barrieau, Concordia University. *The Automation of Public Transit.*

Jean-Pierre Médevielle. *Birth and Development of ITS in France.*

Genevieve Richard. *How the Elevator Changed the City.*

12:15 p.m. **Lunch Break**

1:30 p.m. **Presentation Followed by Group Discussion**

Johanna Zmud, Insights from the recent RAND Corporation Study, *Autonomous Vehicle Technology: A Guide for Policymakers*.

2:00 p.m. **Panel of Three Experts. How to Move into the Future: Addressing Transportation, Technology, and Societal Needs and Responses**

Joshua Schank, President, Eno Foundation; Philip Tarnoff, Director Emeritus, Center for Advanced Transportation Technology and Author of *The Road Ahead*; and Steven Lockwood, Senior Vice President, Parsons, Brinkerhoff, Quade and Douglas.

3:15 p.m. **General Discussion**

Moderated by Martin Wachs.

What to Do Next? Potential research project statements for NCHRP–TCRP; potential actions by the JPO, potential programming by the TRB History Committee for the 2015 Annual Meeting. Written summary of the discussion to be circulated among all participants following the workshop.

4:30 p.m. **Adjourn**

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Ralph J. Cicerone is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. C. D. Mote, Jr., is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the National Academies of Sciences, Engineering, and Medicine to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.national-academies.org**.

The **Transportation Research Board** is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to increase the benefits that transportation contributes to society by providing leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

Learn more about the Transportation Research Board at **www.TRB.org.**

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