2015 VASEM SUMMIT REPORT

VOLUME 1 **VEHICULAR TRANSPORTATION**

VIRGINIA ACADEMY OF SCIENCE, ENGINEERING, AND MEDICINE

VASEM

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MESSAGE FROM THE PRESIDENT

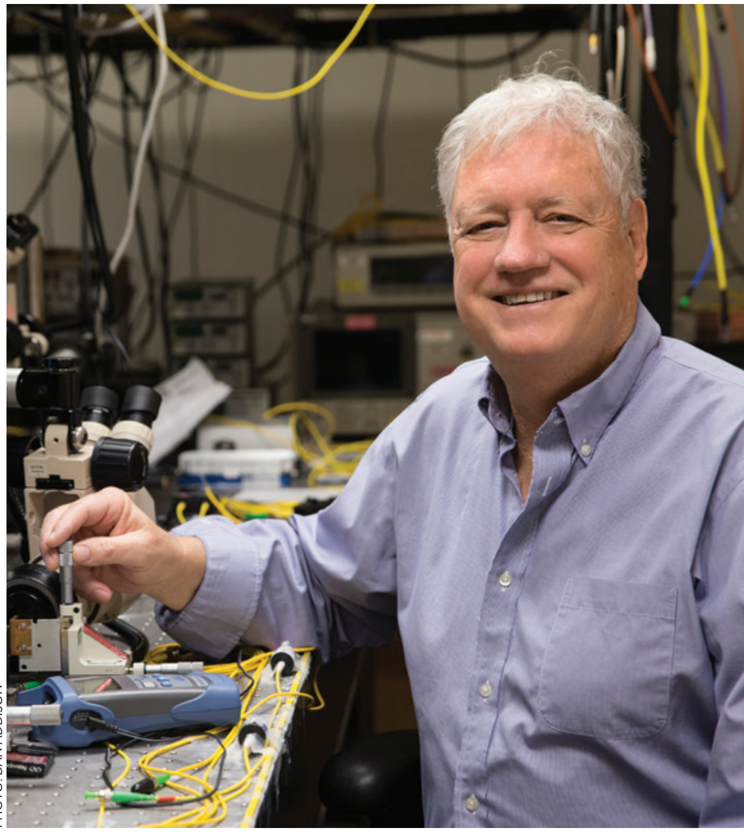


PHOTO: DAN ADDISON

These two volumes of presentation summaries from our 2015 annual meeting in November reflect the expertise that the Virginia Academy of Science, Engineering, and Medicine (VASEM) can bring to bear on issues that are important to the future of Virginia. In this case, we chose two topics identified by the VASEM board in consultation with leaders around the Commonwealth such as Secretary of Technology Karen Jackson. The first, covered in this volume, are the forces reshaping vehicular transportation and the likely evolution of this sector. The second volume concentrates on the complex challenges entailed in harnessing the vast potential of unmanned aerial systems.

The consequences of our annual meetings are as important as their content. Our purpose is to bring together the Commonwealth's foremost scientists, engineers, and medical professionals in a setting that encourages the exchange of ideas across the disciplines. We ask each member to bring with them a colleague of exceptional promise, and we invite representatives of industry and government agencies to join the conversation. Our intention is to catalyze new ventures and new initiatives, harnessing the expertise, experience, and enthusiasm that only a group of this caliber and diversity can muster.

This process works. There are already several examples of research collaborations that have been seeded at our annual meetings.

This event—and the series of discussions we orchestrate each year with government and industry leaders throughout the state—has gone far to raise awareness of VASEM and the role we can play as a nonpartisan group of experts in creating a better future for our state. Our goal is to serve Virginia in much the same way as the National Academies serve the nation.

None of this progress would have been possible without support and guidance from Senator Mark Warner. He has been instrumental in establishing VASEM and sustaining our organization during its formative years. I would like to take this opportunity to thank him for his efforts.

Sincerely,

Joe C. Campbell

Joe C. Campbell
Lucien Carr III Professor of Electrical and Computer Engineering
University of Virginia

CONGESTION AND RELIABILITY

CONNIE SORRELL

Connie Sorrell, president of Sorrell Consulting and former chief of system operations for the Virginia Department of Transportation, opened the afternoon session by noting that she had left Richmond that morning at 8:45. Her goal: to reach the National Academy Building in Washington in time for her 1:00 presentation no matter how bad the traffic on Interstate 95 might be. "You never know," she said, "if that two-hour trip will take two or four hours."

As drivers in urban and, increasingly, in rural communities know, her experience is not unusual. Sorrell cited statistics compiled by researchers at the Texas Transportation Institute for the *2015 Urban Mobility Scorecard* to illustrate how bad congestion has become. They found that travel delays due to traffic congestion caused drivers to waste more than 3 billion gallons of fuel and kept travelers stuck in their cars for nearly 7 billion extra hours per year—42 hours per rush-hour commuter. In Washington, D.C., which tops the list of gridlock-plagued cities, drivers spent 82 hours a year—almost 3.5 days—stuck in traffic. The total nationwide price tag: $160 billion, or $960 per commuter.

In this environment of steadily worsening congestion, Sorrell believes that the second Strategic Highway Research Program (SHRP 2) could represent a turning point. Congress funded SHRP 2 in 2005 to target goals in four interrelated focus areas: safety, renewal, capacity, and reliability. This was a major effort, costing $218 million, requiring input from 158 committees, and involving contracts with more than 400 research organizations. Hundreds of reports, tools, and more came out of this project.

TOM SAUNDERS, VDOT

TOM SAUNDERS, VDOT

RELIABILITY IN THE SPOTLIGHT

In Sorrell's view, one reason that SHRP 2 was noteworthy was that it was the first time that reliability had been a focus of such a large-scale investigation. "'Reliability' is a relatively new word in the transportation lexicon," Sorrell pointed out. "It is, however, what consumers and commuters are most concerned about: if a trip takes on average 20 minutes, it should always take 20 minutes. They need this information to plan their lives, get to work on time, and make sure their children are on time for soccer practice." The goal of the SHRP 2 reliability focus area is to make on-time arrival predictable and routine by tackling recurrent conditions that cause congestion and nonrecurrent events.

The authors of SHRP 2 elevated travel time reliability (TTR), a probabilistic concept, as an effective tool to achieve these goals. From a driver's point of view, TTR means the ability to count on a given trip having a particular duration each time. From a technical point of view, TTR has the advantage of being something that can be quantified and measured. It can be used to develop performance measurement and monitoring systems, inserted in traffic simulation and other models, and incorporated in highway planning and design methods.

For these tools and processes to be used effectively, they must fit into an institutional setting that emphasizes operational management of the highway system. Accordingly, SHRP 2 also addresses institutional factors, such as business practices, interorganizational collaboration, and training. "We came to realize at the beginning of the 21st century that we really needed to take the limited resources we had for transportation and think about how we can operate the network to maximize its efficiency," Sorrell said.

Accordingly, SHRP 2 included a number of broad initiatives:

- A framework for systematically improving an agency's transportation systems management and operations resources and capabilities
- Tools to analyze reliability at the planning, design, and operation levels
- Methods to develop effective data collection systems and performance monitoring programs
- Assistance in developing performance measures
- Training programs for system management and operations professionals as well as traffic incident responders

During her presentation, Sorrell gave numerous examples of specific initiatives in each of these areas. As part of the effort to build institutional capacity, the Transportation Research Board (TRB) produced a report titled *Integrating Business Processes to Improve Travel Time Reliability* and an interactive software tool to help agencies apply the seven-step approach advocated in the report. Another report showed how departments of transportation and metropolitan planning organizations could adapt the capability maturity model widely used in technology industries to conduct an organizational self-assessment and continuous improvement analyses. The American Association of State Highway and Transportation Officials posted a tool based on this concept on its website.

Sorrell also highlighted a number of training and awareness efforts, including a classroom curriculum that has been delivered to more than 100,000 traffic incident responders that increases their capacity to work together to clear incidents more efficiently and safely, thus reducing congestion.

Researchers under the SHRP 2 umbrella produced a guide that will help agencies set up reliability monitoring programs that can be inserted into their existing systems as well as the software and documentation they need to integrate TTR into their models. They also produced guides to highway design to reduce nonrecurrent congestion, which set the stage for incorporating TTR into the *Highway Capacity Manual*, one of the most widely used transportation reference books in the United States.

Sorrell noted that all the SHRP 2 reliability results have been brought together, along with other materials, in a new National Operations Center of Excellence, designed as a single source for reliability and systems management and operations guidance and products.

THE FUTURE OF RELIABILITY

The authors of SHRP 2 envisioned a future in which TTR is a primary performance measure for agency and user decisions nationwide, TTR content is in leading technical manuals, and TTR curricula are taught in educational and training settings. It is also a future in which operations and management programs are commonplace at state, regional, and local agencies and SHRP 2 products are in everyday practice.

As Sorrell points out, SHRP 2 has already been influential. The *Moving Ahead for Progress in the 21st Century Act (MAP-21)*, which funded surface transportation for FY 2014 and 2015, included national performance goals for congestion reduction, and the Federal Highway Administration created a Congestion Reduction Toolbox. In Virginia, the Department of Transportation has shifted its focus to operations and systems management and has launched a series of initiatives that include the deployment of active traffic management technology on I-66 and the creation of a new integrated command center in Northern Virginia for traffic operations.

Sorrell concluded by emphasizing that there is no single silver bullet for alleviating congestion and increasing reliability. Referencing the *Urban Mobility Report*, she emphasized that all of the potential congestion-reducing strategies must be considered—including issues that are not the purview of departments of transportation, like high-density development and work routines that emphasize flexible scheduling and home offices. Nonetheless, she concluded, "the mix of solutions is less important than the amount of solutions implemented."

Connie Sorrell, PhD, is president of Sorrell Consulting and former chief of system operations for the Virginia Department of Transportation, where she was responsible for a $1.4 billion budget. Among her other accomplishments, she created a new organizational structure/programs to focus on maintenance and operations of 127,000 miles of roads with emphasis on developing/deploying operational strategies to reduce congestion.

Travel delays due to traffic congestion caused drivers to waste more than 3 billion gallons of fuel and kept travelers stuck in their cars for nearly 7 billion extra hours—42 hours per rush-hour commuter.

TRANSFORMATIONAL TECHNOLOGIES IN TRANSPORTATION

MARK R. NORMAN

"I have been working in transportation for more than 40 years, and I can't ever remember a more exciting time," said Mark Norman, the director of program development and strategic initiatives at the Transportation Research Board (TRB), introducing his presentation on transformational technologies. "I am not talking about innovations or incremental improvements, but about disruptive technology, technology that will make a big difference in the way we work and live and certainly in the way we travel."

For the purposes of this presentation, Norman focused on two disruptions— the first, connected and automated vehicles, and the second, the shared economy—that have been made possible by a convergence of technological factors, including personal computers, the Internet, smartphones, GPS, and big data.

CONNECTED AND AUTOMATED VEHICLES: POINTS AND COUNTERPOINTS

From his post at the TRB, Norman is well positioned both to encounter claims advanced for connected and automated vehicles and to evaluate them. In his presentation, he provided point and counterpoint for several of the most common.

Connected-Automated Vehicles Will Be Available to the Public by 2020

Thanks to the well-publicized automated car projects that companies like Google and Tesla are conducting, the public has assumed that the age of automated vehicles is right around the corner. Not so fast, Norman said. In his view, automation in vehicles will evolve in stages. "Layers of automation will be added over time," he said. "It will begin with connected vehicles, where the driver is still primarily in control, and then gradually evolve to the point when the vehicle is primarily in control.

Connected-Automated Vehicles Will Be the Biggest Transformational Change since the Invention of the Automobile

Although Norman himself leans toward this view, he asserted that realizing the full potential of automated vehicles would not be straightforward. He noted that adoption of these technologies will be market driven—and while we can point to societal benefits gained by automated vehicle technologies, not all of these, like less energy consumption, are selling points for most consumers.

For the Federal Government, the Transition to Connected-Automated Vehicles Will Be the Next Interstate Program

Certainly, Norman said, the federal government will have a critical role to play, intervening to create uniform standards and allocating spectrum for data transmission. But this is not the 1950s. The regulation and registration of vehicles, the licensing of drivers, and the promulgation of traffic laws and ordinances are under the control of the states. Ultimately, however, it will be the private sector that will lead the way toward the widespread adoption of this technology.

Connected-Automated Vehicles Must Be Connected with the Infrastructure to Be Successful

The Department of Transportation, many state departments of transportation, and automobile manufacturers believe that two-way communication between automated vehicles and the surrounding infrastructure is the way to achieve the full benefit of these technologies. Given constraints on public funding, however, Norman believes it will be a challenge for the public sector to be able to keep pace with private sector advances in these technologies.

Right now, there are two autonomous alternatives. The first is the traditional something-everywhere approach that most auto manufacturers have adopted as they introduce features like adaptive cruise control. The other is Google's Self-Driving Car Project, an everything-somewhere approach, designed to bring autonomous cars to lower-speed urban areas. "It will be interesting to see if these two approaches converge," Norman said.

Connected-Automated Vehicles Will Eliminate 80 Percent of Serious Accidents

Human error is responsible for 80 to 90 percent of serious crashes. Proponents of automated vehicles argue that taking human beings out of the equation will reduce accidents. As Norman pointed out, there is another way to look at accident figures: a serious accident occurs with a fatality or serious injury once every several million vehicle miles of travel. The new systems have to replicate all of the things human beings do right while correcting the few things we do wrong. That's a high bar, he suggested.

PHOTO: GOOGLE

Connected-Automated Vehicles Will Eliminate Congestion

Norman said it is possible to imagine an ideal future in which automated vehicles redirect themselves to follow the best routes, travel at the optimum speed for the traffic, and operate at a safe distance from the vehicles in front of them. But automated vehicles might be undone by their own success. By making driving so much easier, they may encourage trips that are more frequent and longer. There is one point that Norman feels we can agree on: we have more questions than answers, with research being the key to providing those answers.

TRANSPORTATION NETWORK COMPANIES AND THE SHARED ECONOMY

In discussing the shared economy as a disruptive force in transportation, Norman previewed the findings of a TRB report, *Between Public and Private Mobility: Examining the Rise of Technology-Enabled Services*, which was released in December 2015. These technology-enabled services include everything from bike-sharing initiatives like Citi Bike in New York, car-sharing services like Zipcar, ride-sharing and transportation network companies (TNCs) like Uber and Lyft, and microtransit companies like Bridj and Leap.

Norman devoted most of his attention to the TNCs. Their business model is simple. Customers use smartphones to connect with the company and pay for their ride. The company takes a percentage of the fare, and the driver, who owns the vehicle, keeps the rest. These companies have been very successful. Uber is valued at more than $50 billion, has a presence in 58 countries and more than 300 cities, and works with 160,000 drivers.

The promise of these services is straightforward: they have the potential of increasing mobility while reducing congestion and emissions from surface transportation. Whether they realize this promise remains to be seen. As Norman pointed out, the rapidly expanding services provided by TNCs raises a number of questions.

Access can be a problem. "If you don't have a credit card or own a smartphone, you are out of luck," Norman said. TNCs are not required to have wheelchair-accessible vehicles, which means many people with disabilities will in many cases continue to rely on public paratransit services.

Safety and security is another unresolved issue. The taxi industry typically fingerprints drivers. Uber and Lyft run checks against the driver's name, birthday, social security number, and driver's license number. Norman pointed out that there is little analytical evidence of which method is more effective.

Perhaps the largest unresolved issue, in terms of the TNC business model, is the classification of drivers as contractors. In June, the California Labor Commission issued a ruling that an Uber driver is an employee and other lawsuits are pending. Uber is appealing.

Norman closed by asking whether traditional research processes are nimble enough to prepare public agencies for an age of transformational technologies. He suggested that it might be worthwhile to look at models used by other sectors or develop new models that can provide a more continuous stream of answers to the questions that require our immediate attention.

Mark R. Norman, PE, is the director of program development and strategic initiatives at the Transportation Research Board, a division of the National Academies of Sciences, Engineering, and Medicine. He is responsible for ensuring stable, long-term revenue streams for TRB and for coordinating strategic initiatives across the board's various divisions.

TRANSPORTATION AND SAFETY

THOMAS DINGUS

In 2013, the last year for which statistics were available, 32,719 people died in motor vehicle crashes. In his presentation, Thomas Dingus, director of the Virginia Tech Transportation Institute (VTTI), highlighted some of the innovative techniques his organization has developed to shed light on the causes of crashes and to identify and evaluate countermeasures to reduce them. With an annual budget of $45 million, VTTI is home to the largest group of driving safety researchers in the world.

A PIONEER IN NATURALISTIC DRIVING STUDIES

Vehicles in the United States are reliable and the roadways are very good, Dingus pointed out. It is human performance that contributes to more than 90 percent of crashes. Twenty years ago, engineers at VTTI realized that if they wanted to understand what caused crashes they needed better data. "We had epidemiological data from crash databases," Dingus said, "but these data didn't shed light on what happens during the seconds leading up to a crash. We had the results of empirical studies, but these were performed under controlled conditions, frequently on a simulator and not in the real world."

In response, VTTI developed naturalistic driving studies, which involves equipping the vehicles of volunteer participants with unobtrusive cameras and instrumentation to record actual driver behavior and performance. This can include multiple channels of video as well as radar, machine-vision eye- and lane-tracking, and vehicle network data recording. There is no experimenter present, and participants drive as they normally would.

VTTI has collected data from more than 4,000 drivers, in some cases for up to three years, who have traveled more than 40 million miles. In the course of its investigations, it has recorded more than 1,500 crashes and minor collisions. "You can literally watch crashes unfold," Dingus said. "You can analyze everything frame by frame, from where drivers are looking to when they apply the brake."

Thanks to this approach, VTTI researchers have gained significant insights about how the driver, the vehicle, and the infrastructure interact in the driving environment. More than a decade ago, VTTI led the 100-Car Naturalistic Driving Study, which was the first large-scale study of its kind ever conducted.

In 2007, VTTI took a leadership role in the second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study. The study followed more than 3,000 volunteers from six locations taking over 5 million trips. It generated more than 2 petabytes of continuous naturalistic driving data, representing the equivalent of four millennia of driving time. In the course of this travel, researchers captured 845 property damage and injury crashes, and examined each one looking for observable impairment, driver performance error, driver judgment error, and observable driver distraction. In addition to noting the prevalence of different kinds of activities, they created odds ratios—how much more or less risk one encounters when engaging in these kinds of activities—compared to alert, attentive, sober drivers.

"The results definitely show a distraction epidemic, with drivers doing something in addition to driving more than 50 percent of the time," Dingus said. Dingus and his team have submitted a paper to the *Proceedings of the National Academy of Sciences* that presents their findings in detail. In the meantime, VTTI plans to keep between 500 and 600 vehicles on the road and plans to expand its naturalistic database, increasing its power and usefulness.

COUNTERMEASURE ANALYSIS

VTTI's research into the causes of crashes provides the foundation for its efforts to reduce them, Dingus said. Since it began its countermeasure program in 1996, it has tested virtually all the active safety systems that automobile manufacturers offer, as well as many that will be adopted in coming years. These include forward-collision warning, lane-departure warning, and blind spot monitoring. For instance, one reason that back-up cameras are being adopted by carmakers is that VTTI researchers demonstrated that a simple alert was insufficient in preventing injuries.

PHOTO: LOGAN WALLACE

PHOTO: JUSTIN FINE

"Such systems are continually evolving," Dingus said, "and now often include automated control. They have to be developed carefully to ensure they do not cause unintended consequences that lead to a reduction in driver safety."

The next step in safety—and a stepping stone to robust and reliable automated vehicles—are connected vehicles, which communicate with other vehicles, with the infrastructure, and with devices like smartphones. Using a combination of dedicated short-range communications and cellular technology, connected vehicles have the potential to increase mobility, mitigate negative environmental impacts, and enhance safety. Dingus observed that the National Highway Transportation Safety Administration concluded that connected-vehicle technology could help eliminate approximately 70 percent of crashes involving alert drivers.

In conjunction with the University of Virginia, Morgan State, and the Virginia Department of Transportation, VTTI has 29 projects under way examining applications in such areas as dynamic rerouting, roadway icing, and work zone safety.

In the meantime, VTTI is deeply involved in vehicle automation, working in many instances with Silicon Valley automated car companies. "Vehicle automation development is progressing at a rapid pace but is challenging," Dingus said. "The bar that automated vehicles have to cross is very high." He cited a number of conditions that they have to meet, including delivering very high levels of reliability and safety, operating ubiquitously across state lines and in all roadway, traffic, and driver scenarios, and providing robust protection against cyber attacks.

Although vehicles are automated, Dingus underscored that they are not self-sufficient. Automated vehicles must not only reliably understand what is going on around them but also understand the state of the driver. When they fail, they must be able to do so in a way that provides the driver adequate time to assume control. In some levels of automation, like SAE Level 2, where drivers have their hands and feet off the controls, drivers still need to pay attention. Six manufacturers are coming out with Level 2 automation next year.

Another challenge that Dingus noted is finding places to test them. Predeployment testing requires complex vehicle interaction scenarios and real roadway environments, but the availability of real-world test environments is extremely limited due to reliability and safety concerns. VTTI is fortunate in having its Smart Road Test Bed, which opened in 1998. It has also created a partnership with VDOT for Virginia Connected Corridors and joined with VDOT, DMV, Here, and Transurban on the Virginia Automated Corridors project. "We are building an environment where we can test any vehicle on any Virginia road with no restraint other than our normal institutional review board safety precautions," Dingus said. The Virginia Automated Corridors program provides a system migration path from Smart Road to real-world operating environments for multiple projects, incorporates an operational environment that features myriad transportation challenges, and provides realistic and modern connected-vehicle infrastructure environment.

As Dingus points out, perhaps the biggest challenge to automated vehicles is the persistence of manual driving. "If people started to buy automated vehicles today, it would take 25 years for us to complete the turnover," he said.

Thomas A. Dingus, PhD, CHFP, is director of the Virginia Tech Transportation Institute. VTTI is the pioneer in naturalistic driving studies, housing more than 40 million miles of continuous naturalistic data from more than 4,000 drivers.

» Automated vehicles must not only reliably understand what is going on around them but also understand the state of the driver.

TRANSPORTATION AND ENERGY: MANAGING AN ENERGY TRANSITION

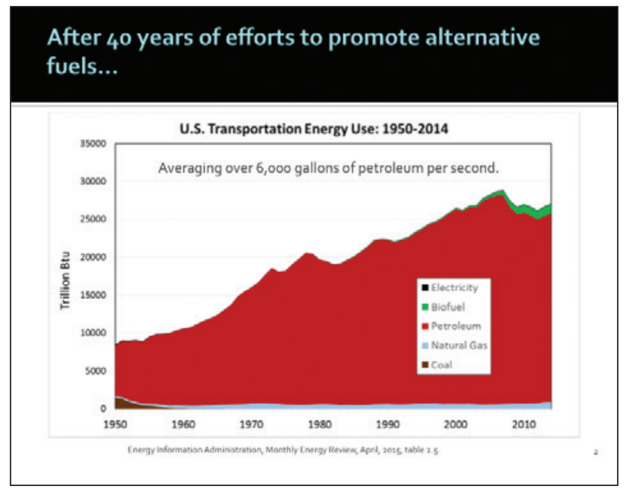
DAVID GREENE

"When I asked Professor Campbell what I should talk about, he said just pick the most exciting and interesting topic you know of," said David Greene, a senior fellow in the Energy & Environmental Policy Program of the Howard H. Baker Jr. Center for Public Policy at the University of Tennessee Knoxville. "To me, that is the challenge of making the transition in the energy-transportation system from petroleum to something that is low in carbon and renewable."

Greene pointed out that if this transition were easy, it would have been accomplished in the years following the oil crises of 1973–74 and 1984. Today, the U.S. transportation sector is still 95 percent dependent on petroleum for energy, consuming an average of 6,000 gallons of petroleum per second.

There have been a number of compelling reasons, according to Greene, that it has been difficult to wean the transportation sector from petroleum. The first is that petroleum fuels are the most energy dense form of fuel available. He also added that they are easy to transport and easy to store. The second reason is that petroleum is abundant. By an order of magnitude, there is more liquid fossil fuel in the ground than has already been used since the beginning of the industrial era—and it can be delivered to consumers at prices they have already shown themselves willing to pay.

But for Greene, the dangers of our continued reliance on petroleum are equally obvious. He noted that transportation emissions contain large quantities of greenhouse gases, primarily carbon dioxide, but also hydrofluorocarbons. Highway vehicles account for the majority of these emissions. If society is to limit global warming to 2 to 3 degrees centigrade, it must adopt an alternative to petroleum for transportation by midcentury.



TRAVEL REDUCTION

Greene laid out three strategies to accomplish this goal—reduce travel, substitute low-carbon energy sources, and increase energy efficiency—and analyzed the effectiveness of each one.

He was not sanguine about the potential of reducing travel. Greene noted that there have been only a few events in the history of the United States that have interrupted the inexorable growth of highway vehicle travel in the U.S. They include the Great Depression, World War II, and the first and second oil price shocks. Most recently, travel declined temporarily in the aftermath of the Great Recession, due to a combination of factors that included high oil prices and income stagnation. This was the longest period of no or negative growth in our transportation history, but more recent data shows travel growth resuming. Greene mentioned that initiatives involving land use and nonmotorized transportation have been successfully implemented in parts of the country, but that it remains to be seen if they will materially slow travel growth.

LOW-CARBON ENERGY SOURCES

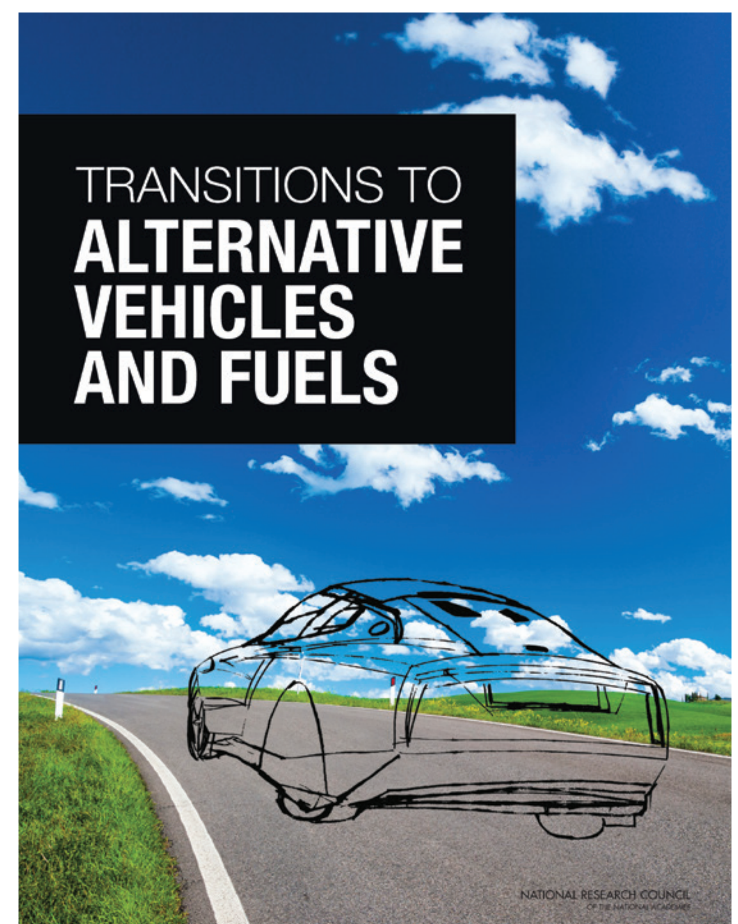
Biofuels have been the most the successful nonpetroleum source of energy in the transportation system. Greene noted, however, that their application is limited by the sheer amount of land needed to produce them in meaningful amounts. The U.S. Department of Agriculture and the Department of Energy projected that the maximum amount of biomass that could be produced for energy purposes is about 1 billion dry tons. Even under the most optimistic scenarios—using high-efficiency conversion technologies that have not yet been perfected—very little of this biofuel would likely be available for light-duty vehicles due to competition from other potential uses such as aircraft or heavy trucks.

ENERGY EFFICIENCY

The way forward, Greene said, is energy efficiency. In 1975, President Gerald Ford signed the Energy Policy and Conservation Act, which created the corporate average fuel economy (CAFE) standards. These standards, Greene said, are the principal reason that fuel use has become decoupled from vehicle travel. In 2012, we were using 80 billion fewer gallons of gasoline than we would have been using were it not for improved fuel economy.

Greene participated in a 2013 NRC study, *Transitions to Alternative and Vehicles and Fuels*, that attempted to determine what it would take to produce a 50 percent reduction in petroleum use by light cars by 2030 and an 80 percent reduction by 2050. Greene and his colleagues determined that if you take advantage of advanced technology, use biofuels, and employ a system of indexed highway user fees, the United States could achieve a 64 percent petroleum decrease and a 52 percent greenhouse gas reduction by 2050, falling short of its goals.

They identified two technologies that have the potential to bridge the gap to their goals. The first is the fuel cell electric vehicle powered by hydrogen produced using an ultra-low-carbon renewable energy source—wind, solar, or electrolysis. The second is the plug-in electric vehicle powered by an ultra-low-carbon grid.



Greene observed that there has been tremendous progress in commercializing both of these technologies over the last two decades. The fuel cell in Daimler's 1994 prototype occupied the cargo space of a full-size van. The fuel cell in its 2014 F-Cell test car fits into a sedan. The engine is rated at 100 kilowatts and has a range of about 400 kilometers. It refuels in three to five minutes like a gasoline-powered car. The major challenge is the price. "The consensus is that the cost per kilowatt of fuel cell systems must come down to the $25 to $30 range to be truly competitive," he said. Greene cited similar improvements for plug-in battery-powered vehicles, but here again, price is a barrier.

MAKING THE TRANSITION

In the case of fuel cells, planners also must account for the cost of a transition to hydrogen infrastructure, among other natural market barriers. "It's a chicken-or-egg problem," Greene said. "If there are no vehicles that use hydrogen, who is going to put hydrogen stations in place? If there are no hydrogen stations, who is going to buy a hydrogen vehicle?" He noted that he and his colleagues identified other natural market barriers such as risk aversion of consumers, lack of scale economies, and insufficient diversity of choice that require further investigation. They found that the total benefits of the transition—including greenhouse gas mitigation, uncounted energy, petroleum reduction, and consumer surplus—exceeded its cost by roughly $1 trillion.

The large-scale energy transitions in the past, Greene noted, were driven primarily by technological change and market forces. They took a long time. "What we are trying to do now is completely different," he said. "Our objective is to achieve the public good, to protect the environment, and achieve sustainable energy use. So public policy has to play a central role in the process."

Greene believes that we need a new policy paradigm to accomplish this goal, one that accommodates time constraints, deep uncertainty, and strong positive feedbacks as well as new planning methods and tools to coordinate massive investments in vehicles and infrastructure. "This is going to be interesting, difficult, and challenging—and the most exciting period in transportation and energy to date," he concluded.

David L. Greene, PhD, is a senior fellow in the Energy & Environmental Policy Program of the Howard H. Baker Jr. Center for Public Policy at the University of Tennessee Knoxville and a research professor in its Department of Civil and Environmental Engineering.

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VIRGINIA ACADEMY OF SCIENCE, ENGINEERING, AND MEDICINE

The Virginia Academy of Science, Engineering, and Medicine is a nonprofit organization comprising members of the National Academy of Science, National Academy of Engineering and Institute of Medicine who reside or work in Virginia.

VASEM's mission is to assist the Commonwealth of Virginia by serving as an intellectual resource to inform and educate agencies on issues for which science, engineering, and medicine affect decisions on policy, on the economy, and on the quality of life. The organization will promote research, foster interchange between individuals and organizations, and recognize and honor individuals in the Commonwealth who have made major achievements in science, engineering, and medicine.

Senator Mark Warner is the honorary chair of the VASEM board of directors.

PHOTO: JACK BELHART, VDOT