The Ongoing Transformation *of the* Global Transportation System

A U.S. DOT Volpe Center Thought Leadership Series

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U.S. Department of Transportation
Volpe Center

Notice

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The Ongoing Transformation of the Global Transportation System: Series Introduction

Thought leaders, decision makers, and stakeholders from across the global transportation enterprise visit the U.S. Department of Transportation's Volpe National Transportation Systems Center to discuss future transportation challenges, generate fresh approaches to emerging issues, anticipate trends, and inform decision making.

The Ongoing Transformation of the Global Transportation System, held from September to December 2017, convened seven distinguished experts in transportation entrepreneurialism, design, policy, and economics to explore challenges and opportunities affecting the advancement of multimodal transportation systems.

The themes these speakers discussed cut across each of the U.S. DOT's strategic priority areas: safety, infrastructure, innovation, and accountability.

Speakers brought their bold visions for the transportation systems of tomorrow, from robot porters that can carry groceries, to cars that turn into airplanes.

They challenged transportation professionals to think critically about the cybersecurity implications of automation, how humans and autonomous systems interact, the impacts that autonomous cars may have on policy frameworks, and what it means to live a long, high-quality, fully mobile life.

And, they presented brand new data on the performance of our nation's highways. Read on for more of the insights and innovations that are supporting the U.S. DOT's core priority areas—plus, watch video highlights from each speaker.

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U.S. DOT Volpe Center director Anne Aylward introduces The Ongoing Transformation of the Global Transportation System.

An audience member engages with Harvard's Jeffrey Schnapp.

Penn State's Amy Pritchett answers a question from the audience.

Autonomy for Humans in the 21st Century City

Jeffrey Schnapp, PhD
Co-Director, Berkman Klein Center for Internet and Society
Founder/Director, metaLAB (at) Harvard

September 21, 2017. How did the human cross the road? By moving in a steady flow with other pedestrians, drawing on experience to anticipate the movements of speeding, braking, and turning vehicles, and making decisions in an instant based on a dizzying amount of information.

How will vehicles navigate physical challenges—including pedestrians, bicyclists, and other vehicles—in those complex urban environments that humans manage as second nature?

"Autonomy for humans for me means a human-centric vision of what cities might be, not an automobile-centric one," said Jeffrey Schnapp. "I think that's what this revolution in transportation is all about."

Transportation Innovation That Focuses on the Human Scale

Every day, people who live in cities walk on sidewalks and cross streets, maneuvering around each other and motorized vehicles. Yet much of the history of transportation has focused on mobility beyond the human scale, Schnapp said. Cars, trucks, trains, and ships are meant to move two, three, four, or hundreds of people at a time.

"[These vehicles] are designed precisely to operate in their own roadways or passageways or channels that exceed the scale of the human. Granular mobility, instead, is a kind of mobility that is focused on that fine-grained level, which is the scale of humans themselves."

Smartphones and new transportation technologies are changing how people and goods move, and how transportation experts think about innovation. Advances like autonomous vehicles that fly through the air and drive on streets are breaking ground, but there is room for innovation in vehicles that operate at the human level, Schnapp said.

"Since the 1970s, we've been essentially at a standstill in terms of average speeds of movement," Schnapp said. "The question is really inventing and devising modes of transport that introduce new efficiencies, but efficiencies that contribute to the quality of life, to the lived experiences of the citizens of the cities of the 21st century."

Smaller Vehicles for Human Tasks

One vision for the future of mobility includes smaller vehicles that serve a range of human needs, rather than one big need—getting from place to place. Schnapp presented a concept prototype for a cargo pod on wheels that can carry items like luggage or groceries, turn on a dime, follow its owner, and autonomously travel to different locations.

The prototype cargo pod does not use GPS, which would limit its ability to operate where there is not Internet service, Schnapp said. Instead, the pod's visual navigation system gathers data from its environment as it follows its owner, creating indoor and outdoor maps of the owner's world that it can share with other pods. The key distinction between the maps these pods create and existing GPS maps is that the pod maps are also pedestrian world maps, not maps for large vehicles, Schnapp said.

"Our focus has been on leveraging the power of human navigational expertise. We are expert navigators of sidewalk environments. This is our world. And in the process, trying to extend mobility by offering a multifunctional and multimodal vehicular platform."

Safer at Any Speed: Cybersafety for Connected Vehicles

Joshua Corman
Cyber Safety Innovation Fellow, The Atlantic Council,
Chief Security Officer, PTC

October 5, 2017. Objects everywhere are getting smarter, and increasingly connected. There are refrigerators that can order groceries. There are prescription drug caps that glow when it's time to take the medicine inside. And, of course, there are cars that can drive themselves.

But the more connected things are, the more hackable they become. So far, connectivity is outpacing cybersafety, according to Joshua Corman.

"I like to think not that software is always good, or software is always bad. Clearly we adopt this software and connectivity for the immediate and obvious benefits. We just seldom do the real cost-benefit analysis, to ask ourselves, 'Are the consequences of failure acceptable?'"

Establishing Boundaries to Protect Public Safety

The world of computer coding is very much an open source one. It is a landscape that renounces rules in favor of unbridled innovation. Yet the public expects rules when safety comes into play, Corman said.

"You can't open a restaurant if you can't provide minimum hygiene standards," Corman said. "You can't take a home-built car on the road unless you can demonstrate it's roadworthy. You can't take an airplane into the air if it can't pass safety checks. These technologies and these industries with the potential to affect public safety eventually and appropriately get some level of scrutiny."

A Five-Star Cybersafety Framework for Cars

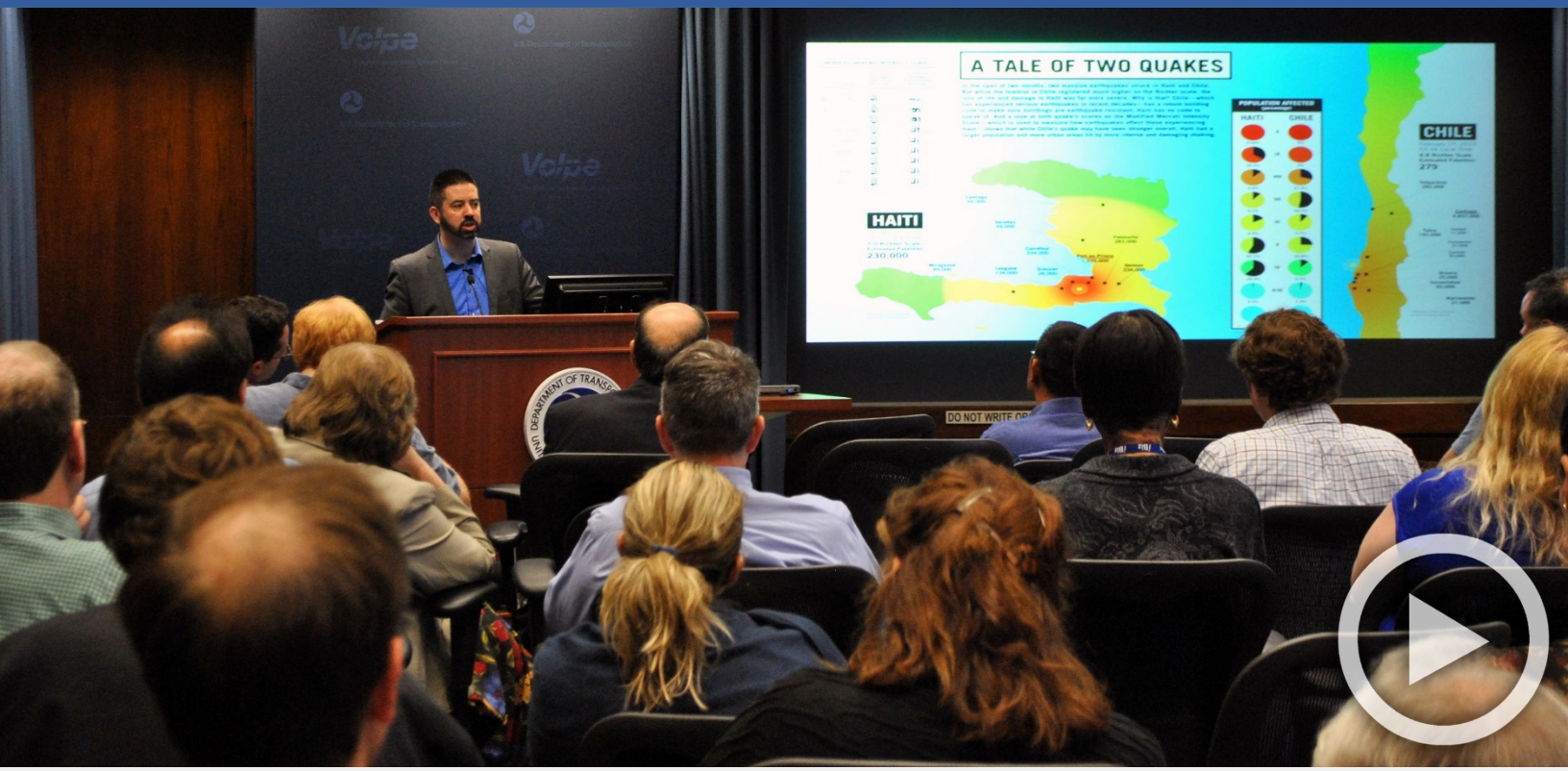
Just as the National Highway Traffic Safety Administration (NHTSA) uses a five-star rating system to assess the physical safety of cars, Corman and his colleagues at the cybersecurity research organization I Am the Cavalry developed a five-star automotive cybersafety program.

"If you're a car company, and you want to be this tall to ride the Internet of Cars, since all systems fail, tell us how you avoid failure," Corman said. "Take help avoiding failure without suing the helper. Capture, study, and

learn from failure. Have a prompt and agile response to failure. And contain and isolate failure."

The five-star framework for automotive cybersafety is not meant to be a regulatory regime or international compliance statute, Corman said. I Am the Cavalary developed it to provide a common language for carmakers, regulators, insurers, and others to begin a constructive conversation on ensuring automotive cybersafety.

"What I'd like us to think about is: with great connectivity comes great responsibility. We should only add that connectivity when we are certain we can rise to the level of commensurate care."



Rethinking the Human-Autonomy Team Architecture

Amy R. Pritchett, PhD
Professor and Head of the Department of Aerospace Engineering
Pennsylvania State University

October 17, 2017. When people and computers interact, it's usually a given that the computer serves as an aide while the human acts as a supervisor. Take the example of an airplane flying at 30,000 feet. The airplane is on autopilot, but the human pilot is ready to take over if air traffic control needs a quick right turn.

With automation appearing more and more across daily life—including in air and ground travel—that division of labor could soon shift. Tasks we think of as belonging to humans may soon be taken over by computers, and there could be consequences that haven't yet been imagined.

"The toaster was once automation—these days we call it an appliance. Automation is a moving target because it goes with our presumption of what is ascribed to the human. And we have a different vision of what the human does. Machines have caught up with that vision. Now we're at a very interesting time in ground transportation and in aviation."

How Automation Can Introduce Complexity

Automation can take specific tasks out of human hands, but automation can also make it more difficult for a human to act as supervisor, she said.

During an average flight, for example, a human pilot is manually flying for just two to seven minutes. The rest of the time, pilots are managing. They are watching outside, talking with air traffic control, and communicating with personnel from their airline, all while being on-call for those two-to-seven minutes.

"As the technology becomes more advanced, human tasks are becoming rare and more difficult," Pritchett said. "It's one thing to supervise an autopilot when you're familiar with hand-flying yourself. But as the systems become more powerful, the amount that you are doing the task—instead of being the manager—goes down. You get pushed further from the core work of flying the vehicle. With that, you're getting pushed out of the cockpit. But you still have to recognize when to step in."

A Shifting Paradigm of Human-Autonomy Interaction

As vehicles of all kinds gain automation, the traditional architecture of how humans and computers interact may get muddy, Pritchett said.

In ground transportation, for example, there are five levels of automation. At level 4, where the driver is mostly not driving but could still have to take over, Pritchett wonders if the driver's operational skills will be up to the task of performing an emergency maneuver.

"Often, particularly in human factors or cognitive engineering, we've accepted the architecture and then quibbled over the interface, the training, the procedures," Pritchett said. "I'd like us to say, 'Is this the right overall structure?"

Capturing the Magic of Human Communication

The secret to a new human-autonomy architecture—at least for air travel—may lie in how commercial pilots interact, Pritchett said. Flight crews often have a seamless, in-the-moment understanding of what needs to happen between two human pilots and the computer.

"There's something about a two-crew operation, when the communication and coordination is working well, that I believe is magic. If we really want to try to bring in more machine function, then this magic is something we need to be able to understand and replicate."

Putting Safety in the Driver's Seat

Harry M. Lightsey III
Executive Director, Emerging Technologies Policy, General Motors North America Public Policy

October 26, 2017. From motorized buggies to muscle cars to four-door family sedans, three core concepts have predominated the past century of innovation in personal automobile travel:

1. A car is owned by an individual.
2. A car is driven by an individual.
3. A car is propelled by internal combustion.

With self-driving cars, cars that talk to each other, and cars that communicate with infrastructure, the paradigm for the next hundred years might look more like this, according to Harry Lightsey:

1. Zero crashes.
2. Zero congestion.
3. Zero emissions.

"We've seen a pretty dramatic increase in the number of crashes on our roads and highways, and in the number of fatalities. We can't ever forget this is a tremendous cost we pay every day for our ability to get around. But we have the opportunity to change all that."

Technology and Society Converge with Self-Driving Vehicles

Technology is advancing, societal trends are changing, and new visions for self-driving vehicles are emerging. New electric car motors, for example, are offering more mileage per full charge. Ridesharing too, in just a few years, has become acceptable and widespread. The challenge now, according to Lightsey, is not to build a vehicle for every consumer, but to build a vehicle that can work in a specific geographic area for multiple short trips.

"Our vision for self-driving vehicles for the foreseeable future is geo-fenced in a limited operating area," Lightsey said. "Fleets of vehicles that are not positioned as retail sale vehicles, but to provide mobility services like ridesharing. That way we can control the fleet when the vehicles are deployed and not deployed."

Meeting Safety Standards Without a Human Driver

Beyond the shorter-term possibility of automated, electric ridesharing vehicles, policy makers and carmakers will need to work together to define a new, longer-term vision for personal automobiles, Lightsey said.

Guidance from the NHTSA and research from the Intelligent Transportation Systems Joint Program Office, NHTSA, and Volpe are helping to clarify that vision.

"It wasn't long after I last talked here that you released the seminal work on looking at where we were with safety standards in terms of how they could accommodate self-driving vehicles at high levels of automation," Lightsey said. "The Volpe report is kind of the bible for that now."

Federal and state legislation will be one big driver of what the future of self-driving vehicles will look like, Lightsey said. Historically, federal legislation has focused on vehicle performance and parameters. At the state level, legislation has focused on driver performance. With self-driving vehicles, that line becomes blurry, Lightsey said—and many regulations explicitly or implicitly refer to a human driver.

"We think there has to be a bridge that gets us from where we are to when we do have rules. We see that bridge as allowing [U.S. DOT] to grant an alternative way to establish vehicle safety. As long as we can establish that the way the vehicle functions has the equivalent safety of a conventional vehicle, then we feel we should be able to put that vehicle on the road."

Leveraging the Space Above Our Heads and the Emergent eVTOL Market

Carl C. Dietrich, PhD
Co-founder and Chief Technology Officer
Terrafugia

November 28, 2017. Getting stuck in traffic isn't just a nuisance. On an aggregate level, traffic can have major financial impacts on cities and countries. Globally, 2 to 4 percent of gross domestic product is lost every year due to congestion, according to Carl Dietrich. One solution to alleviating traffic might be right above our heads.

"People have been flying small aircraft for a hundred years," Dietrich said. "Why don't we take better advantage of the fact that we have this great resource right above our heads?"

A Street-Legal Airplane

Barriers to entry have kept many people away from flying small aircraft, Dietrich said. Pilots need lots of training. Aircraft are very sensitive to weather. There are high ownership costs and long door-to-door travel times, and many general aviation airports have limited ground mobility.

But Dietrich and his company have developed a small airplane that can also be driven on roads—in contrast to a flying car—that is part of a larger trend of investment in flying-vehicle technologies, and that addresses barriers to entry for potential pilots.

"We have this tremendous infrastructure in the United States of over 5,200 public use airports, on average one within a half-hour drive of wherever you are in the country. It's one of the first questions that I always get: 'Can I just take off and land from the street?' No, you go to one of these places—but they're all over the place."

Safe as a Bicycle?

Flying commercially is the safest way to travel. Flying a small aircraft is less safe.

"Statistically right now, flying by general aviation aircraft is safer than riding a motorcycle, but it's not as safe as riding a bicycle, in terms of fatalities per mile," Dietrich said.

Ensuring that general aviation pilots and their passengers feel comfortable and safe is a critical baseline for attracting new pilots. Because loss of control is the biggest cause of general aviation crashes, Terrafugia's vehicle is simple to operate and includes haptic stall warnings so that pilots are more likely to notice and correct a stall.

"There's a lower pilot workload: no mixture, no carb heat, no retractable gear, no prop pitch control, no spoilers, no flaps," Dietrich said. "This is basically as dumb, simple, as flying gets. This is Piper Cub simple. This is stick, rudder, throttle."

The Potential for eVTOLs to Alleviate Car Traffic

The Federal Aviation Administration has not certified any electric vertical takeoff and landing (eVTOL) aircraft, Dietrich said. But, Dietrich and his company are informing industry standards for certifying electric motors for flying vehicles, like eVTOLs, because the market for them could be large.

"The potential market is truly huge, and the potential benefit from enabling that market in terms of global GDP, this is the kind of thing that could actually change things by a percentage point, and that kind of thing is very, very exciting," Dietrich said.

From a technological and performance perspective, it seems feasible that eVTOLs could transport people comfortably, Dietrich said. Major challenges would exist around infrastructure—building enough vertiports to meet demand—air traffic control in urban areas, and community concerns about noise.

"People have been flying small aircraft for a hundred years. Why don't we take better advantage of the fact that we have this great resource right above our heads?"

How Much Time Do Americans Spend Behind the Wheel?

Don Pickrell, PhD
Chief Economist
U.S. DOT Volpe Center

December 4, 2017. America's roads exist to move people and goods quickly and efficiently. To assess road performance in those most basic, critical functions, the Federal Highway Administration (FHWA) teamed with Volpe Center experts to produce reliable, comprehensive new data.

Two of the most important measures for understanding road system performance are travel speed and travel time, according to Volpe Center Chief Economist Don Pickrell.

Pickrell and a team of Volpe Center data experts recently completed an in-depth study for FHWA and produced detailed statistics on travel speeds and vehicle hours traveled (VHT). American drivers spent more than 84 billion hours driving during 2015, according to this new data.

"We measure use of the nation's highway system in excruciating detail, but we know much less about how the system is performing. And so this project was an effort to develop a comprehensive measure of how well the U.S. highway system is performing."

Overcoming Data Challenges

Data that the Volpe team used on travel speed and travel time come from two distinct sources that describe the same road systems. But the segment sections do not match—the sources contain information on different, sometimes overlapping road sections. The Volpe team used geospatial methods to match the data.

"That turns out to be quite a time-consuming and detailed process," Pickrell said. "But we've ultimately succeeded in matching a high proportion of the two networks together."

How Much Do Americans Drive Every Day?

Pickrell and his team sliced up the resulting VHT estimates in several different ways: by state and class of roadway, year-over-year changes, and detailed VHT results for specific road sections.

They examined the number of hours licensed drivers spend traveling each day across every state—a familiar data point for anyone who has been stuck in traffic on their way to work. The Volpe team found that, on average, American drivers spend just under an hour driving every day, Pickrell said. Compare that to .96 hours per day average reported in the 2009 National Household Travel Survey, and 1.1 hours per day reported in the American Time Use Survey.

"We think we're in the right ballpark," Pickrell said. "Those other surveys are both relatively small samples, whereas this is a comprehensive nationwide estimate."

Applying VHT Data to Real-World Questions

The new VHT data will provide the basis for transportation experts to develop reliable estimates of road travel delays for metropolitan areas and nationwide. Because the VHT estimates are constructed from detailed spatial and temporal data, transportation professionals will also be able to distinguish between normal rush-hour delays and delays caused by incidents, road construction projects, special events, or abnormal weather.

"Of course, maybe the most obvious application is to monitor long-term trends in travel speed and time," Pickrell said. "As I indicated previously, these are important measures of the way in which the highway system is performing."

Finally, FHWA and Volpe are interested in how VHT data will shed light on the burden that road travel imposes on the time budgets of households and businesses.

"Time, when you think carefully about it, is the only truly non-renewable resource."

Transportation in a World That is Gray, Delayed, Small, and Female

Joseph Coughlin, PhD
Founder and Director
MIT AgeLab

December 13, 2017. Demography is destiny, according to Joseph Coughlin, founder of the Massachusetts Institute of Technology AgeLab.

Put another way, who we are today will determine the society we live in tomorrow. And today, we are increasingly older. Half of children born in 2007 have a chance of living to age 100. People over eighty-five represent the fastest-growing demographic group.

For politics, policy, and technology, the new demand is that people will live longer, and better, than past generations.

"As transportation professionals, we know that before you do anything, you've got to get there first. I think you're going to start to see transportation rise in the agenda to a higher level than we've ever seen before, in part because of an aging population."

A World That is Gray

As education and income go up, birth rates drop. Falling birth rates in many countries, coupled with longer lifespans, means a population that is older—and, as far as hair color is concerned, grayer.

"2047 is the year I want you to think about," Coughlin said. "2047 is the year that worldwide, we'll have more people over the age of 60 than we'll have children between 0 and 15. Think about how this might change demand, lifespans, activities, and the like."

Older populations will have come of age in an era of high expectations. They will be used to their needs and wants being met. They will be highly educated, comfortable with advanced technology, have considerable disposable income, and want to travel, Coughlin said.

"The White House Conference on Aging has gone for decades, since about 1960—transportation has consistently been a top three issue," Coughlin said. "It has consistently not been addressed with enough time and resources."

Then, there is what Coughlin calls the 50-foot problem. Even if vehicle automation achieves its promise of improving mobility, fundamental elements of a typical trip may remain challenging for older Americans.

“How do you get in the car?” Coughlin said. “How do you go grocery shopping? How do you get the five-pound bag of potatoes and the detergent back into the house? The glue of transportation is about the connections, not necessarily the vehicle.”

A World That is Delayed

For many Americans, life is less predictable than it once was. For that reason, the transportation enterprise is facing new challenges.

“All the models we have built for decades in transportation have been predicated on a very nice, dependable life-stage model,” Coughlin said. “We need to throw that out for a variety of reasons. People at an old age are not doing what they are supposed to be doing.”

Traditional life milestones are being delayed, Coughlin said. People are living with their parents well into their 20s, even their 30s. They are having children later, or not at all. Older Americans are much more active than they once were, starting businesses, getting married, and not easing quietly into retirement.

“Of course, younger workers living at home in the suburbs while we’re building up the city for jobs—that’s fantastic, it’s great for the economy,” Coughlin said. “It’s also going to put a greater strain on journey-to-work transportation systems.”

A World That is Small

Worldwide, 27 percent of people live by themselves—not an overwhelming number, but up 10 percent in the past 15 years, Coughlin said. Because more people are living by themselves, with smaller families, planning professionals are redeveloping urban environments to emphasize smaller living spaces.

And older people who downsize are moving to smaller southern and western cities, Coughlin said. These cities are often college towns, where there are interesting people, cafes, sports, and medical care.

“A fundamental mobility gap is about to hit the United States in the next five to fifteen years in a way we’ve never seen before,” Coughlin said. “Transportation and aging has always been defined around disability, health, and access to care. What we’re about to see now is we’re not

going to have access to the things that keep us happy, that make us smile, and being able to support where we live."

A World That is Female

Consumption and choices about which goods to buy have historically been driven by women. That hasn't changed. Eighty-five percent of millennial women are in charge of household cleaning, 82 percent are in charge of cooking meals, and 91 percent are in charge of buying groceries, Coughlin said.

"Women are not just the chief consumption officer," Coughlin said. "The transportation system has always been structured around the journey to work. Now we need to really pay more attention to trip-chaining and getting tasks done."

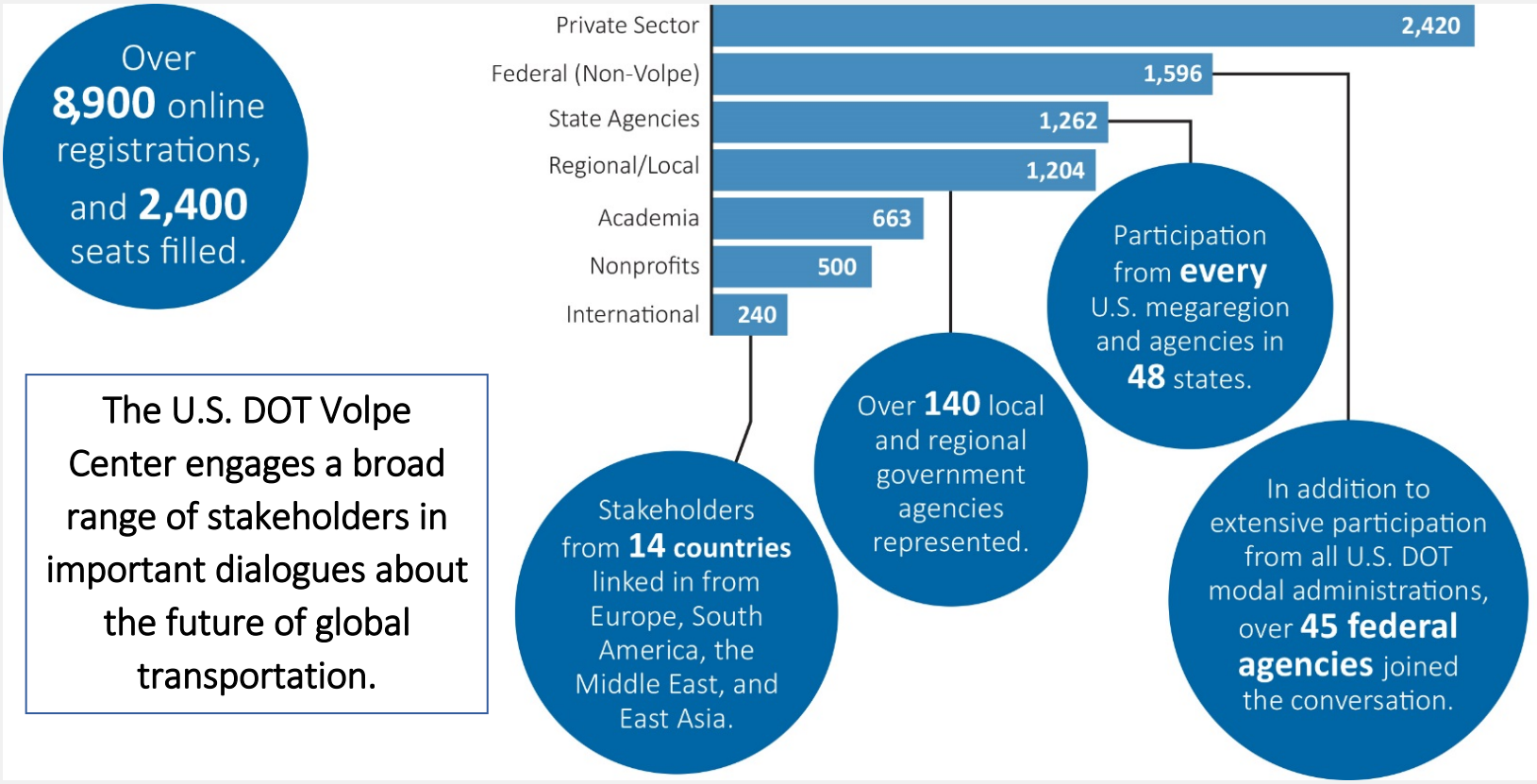
In addition to rethinking transportation planning, an aging population that is more female will require innovations in vehicle design, Coughlin said. The young, adult man has been the traditional model for vehicle safety design. That model, and those designs, may not meet the safety needs of a population that is increasingly older and female.

"Here's the test to know whether you've done your job in transportation for an aging society: Can you get an ice cream cone when you want it? Not, 'Can I go to the doctor?' Not, 'Can I go to the grocery store?' Quality of life is based not on what you need, but that moment on a hot July night when you say, 'I want a soft serve ice cream. Can I go get it?' That's the bar we need to set."

The Ongoing Transformation of the Global Transportation System: Stakeholder Engagement

Over 1,000 unique government, academic, non-profit, private sector and others registered for the U.S. DOT Volpe Center's 2017 thought leadership series, and many engaged in several of the talks. In addition, Volpe Center, U.S. DOT regional staff, and local community members filled the lecture room for talks and engaged with expert speakers during question and answer periods.

The Volpe Center's recent thought leadership speaker series have attracted key stakeholders from multiple sectors. The below chart provides a snapshot of sustained stakeholder engagement from these series over the past four years:



The U.S. DOT Volpe Center engages a broad range of stakeholders in important dialogues about the future of global transportation.

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