Transportation in the Age of Artificial Intelligence and Predictive Analytics

A U.S. DOT Volpe Center
Thought Leadership Series

Final Report

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Volpe Center

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WHAT'S INSIDE

U.S. DOT VOLPE CENTER DIRECTOR ANNE AYLWARD

SERIES INTRODUCTION: TRANSPORTATION IN THE AGE OF ARTIFICIAL INTELLIGENCE AND PREDICITIVE ANALYTICS

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Every year, the U.S. Department of Transportation's Volpe National Transportation Systems Center convenes government officials, academics, and private sector leaders to discuss fresh approaches to future and emerging transportation challenges, and to facilitate knowledge-sharing and inform decision making across modes.

Transportation in the Age of Artificial Intelligence and Predictive Analytics, held from June to October 2018, convened distinguished experts in government innovation, vehicle automation, and logistics to consider the promise and potential of recent breakthroughs in machine learning and data analysis.

These experts shared their bold visions for how new technologies can be applied throughout the transportation enterprise—such as troves of data from mapping applications that can improve traffic modeling and save lives on U.S. roads.

They challenged government professionals at the state and local levels to think critically about how to keep transportation systems safe and moving, recognizing that the time horizon for widespread adoption of innovative technologies can be decades.

They discussed how data is helping freight professionals better understand complex shipping markets. And, they shared how the federal government can encourage transportation innovation without being overly prescriptive.

Read on for more insights on the technologies that are transforming transportation, shaping how we move, and advancing the U.S. DOT's strategic goals of safety, innovation, infrastructure, and accountability. Plus, watch video highlights from each speaker.

U.S. DOT UNDER SECRETARY OF TRANSPORTATION FOR POLICY DEREK KAN

ANALYTICS AND ARTIFICIAL INTELLIGENCE

IN A FEDERAL FRAMEWORK THAT ENCOURAGES TRANSPORTATION INNOVATION

June 4, 2018

Watch the video highlights

A "growing torrent" of technology advances are poised to fundamentally change transportation, according to U.S. DOT Under Secretary of Transportation for Policy Derek Kan, who kicked off Transportation in the Age of Artificial Intelligence and Predictive Analytics.

"Three technology areas are garnering significant investment, testing, and deployment," Kan said. "They are data integration and analytics, automated vehicles, and unmanned aerial systems."

Safety is propelling U.S. DOT programs, and the safety impetus is real. In 2017, 37,133 people died in motor vehicle crashes, down following two consecutive years of large increases. More than 3 million people were injured in motor vehicle crashes in 2016.

Drawing on New Data Analytics to Prevent Road Fatalities

The department has access to a vast amount of data. Looking at that data in new ways may help turn the fatal crash trend south, Kan said. One way is to rethink how U.S. DOT modal administrations collect and organize road data.

"The department's data is often siloed and it comes at different cadences," Kan said. "Data sources are analyzed separately, housed in different modes, and many are only made available on an annual basis. Much of this data has been collected and organized in the same way for years, and maybe even decades. Recent innovations in data science provide the opportunity to do so much more."

Automated vehicles use artificial intelligence, and big-data sources provide previously unseen amounts of information on roadway and operating conditions. This data can help transportation professionals assess fatal crash risk at increasingly granular levels.

"This is one of the big pushes Secretary [Elaine L.] Chao has given us: use the latest technology to prevent traffic fatalities," Kan said.

U.S. DOT established its Safety Data Initiative to do that. Because speed is a contributing factor in many traffic fatalities, one pilot project will integrate established data on crashes and highway design with anonymous data from GPS devices.

For the first time, U.S. DOT will be able to directly analyze how speed—and speed differentials—and roadway characteristics interact to affect the likelihood of crashes.

Another pilot project will integrate crash data with data on hazards and conditions from the crowd-sourced Waze application. This effort will determine if it is possible to use a crowd-sourced application as a reliable, timely indicator of traffic crashes, and to estimate crash risk.

"The vision has always been, 'Let's use new countermeasures—let's deploy capital to install countermeasures, broader roads, traffic circles,'" Kan said. "But there's a whole other way to bring down traffic fatalities, and that's using 0s and 1s—bits and bytes."

Frameworks—Not Prescriptions—for Deploying Automated Vehicles

Volpe Center analysts were closely involved in developing *Preparing for the Future of Transportation: Automated Vehicles 3.0*, released October 2018, which offered a holistic, multimodal framework to accelerate the safe testing and integration of surface automated driving systems.

AV 3.0 builds on *Automated Driving Systems 2.0: A Vision for Safety*, which encourages best practices and prioritizes safety for automakers deploying advanced driver assistance technologies.

As U.S. DOT continues to refine its approach to automated vehicle deployment, it will only pursue regulations that focus on the capabilities those vehicles should have, without prescribing the technologies to achieve those capabilities, Kan said.

"We hope to prepare for the future and encourage innovation without compromising safety," Kan said. "Under this approach, we will not pick winners and losers among technology innovations. We will remain tech-neutral and let the quality of safety performance and market interest drive the evolution of innovative technologies."

Integrating Drones into the National Airspace

Similar to U.S. DOT's approach to automated vehicles, regulations related to unmanned aerial systems (UAS) need to strike a careful balance between ensuring safety and allowing the public and private sectors to boldly experiment with UAS technologies and operations, Kan said.

"The small UAS rule—Part 107—is the first comprehensive set of performance-based rules for routine small UAS operations in the United States," Kan said. "Today, we have 50,000 new commercial drone pilots."

Drone technology and public acceptance are still developing, but U.S. DOT already has several efforts that are striking that balance between public safety and UAS integration.

The UAS Integration Pilot Program is bringing together state, local, and tribal governments with private industry to understand public response to expanded UAS operations. FAA's B4UFLY app is helping UAS operators understand restrictions or requirements in areas where they want to fly. And U.S. DOT is coordinating UAS cybersecurity challenges with partners at the Departments of Defense, Homeland Security, and Justice.

"It's exciting to me to be here," Kan said. "It's an exciting time to be at Volpe because all of you will be playing a critical role in helping form these regulations and usher in new technologies."

CHRIS CAPLICE, PHD, EXECUTIVE DIRECTOR, MIT CENTER FOR TRANSPORTATION AND LOGISTICS

FORECASTING FREIGHT TRANSPORTATION RATES

August 13, 2018

Watch the video highlights

A car driving on an interstate passes a freight truck. The truck is hauling refrigerators at a rate of $2.93 per mile. Down the highway, the car passes another freight truck, hauling televisions at a rate of $2.88 per mile. That other truck further along on the horizon? It's empty, on its way to pick up its next load, and isn't making a cent right now.

The market for buying freight transportation services, in particular trucking services, can be challenging to forecast. There are traditional statistical forecasting models, and models that use artificial intelligence and can incorporate large amounts of data.

How Freight Transportation Markets Work

Before examining different ways to forecast freight transportation rates, it helps to know how freight transportation markets work, according to Massachusetts Institute of Technology Center for Transportation Logistics Executive Director Chris Caplice, PhD.

"Truckload operations are like a taxi cab, not a bus," Caplice said. "You might pick up a load at Reno, take it to Rapid City, drive empty to Denver, pick up another load."

Shippers purchase truck transportation based on two kinds of rates. Contract rates are rates that are set by contract and are fixed over a period of time. They cover 80 to 95 percent of freight trucking volume. Spot rates come from a secondary market, where shippers bid for one-off deals, typically at higher rates than by contract. The spot market covers 5 to 20 percent of volume.

"Contract rates are very different from spot rates, and that is what causes the problem in trying to forecast," Caplice said.

Spot rates are binding. The carrier accepts the load and goes right away. Contract rates, however, are non-binding. Carriers refuse between 5 and 10 percent of loads under contract, Caplice said.

"So what am I going to predict?" Caplice said. "Do I predict the average rate? Do I predict the median? Do I predict the range? This is the challenge. There is more going on than just a single market rate, and this is why there is variability in contract rates."

Using Artificial Intelligence to Develop Market Predictions

Time series prediction is the most popular technique to estimate product demand, Caplice said. With the time series method, the average of the last eight weeks is taken to forecast the next week.

Exponential smoothing is another method that uses past data to predict demand, and also incorporates patterns to identify trends. Another slightly more sophisticated method takes into account that an event from two weeks ago may have a different effect on a prediction than an event from a month ago.

"The problem is that these are good for an individual lane," Caplice said. "A shipper can have thousands of lanes. So running a time series for each lane is time consuming, and I don't know anyone who does it."

Regression analysis, which correlates a host of factors to shipping costs, is useful for long-term prediction, he said. Artificial neural networks, loosely based on the brain's neural network structure, may be useful for predicting short-term rates.

"I had a student, she went and looked at this, trying to predict the next seven days on a lane and do a rolling forecast," Caplice said. "And we're trying to figure out, should I do one big forecast for the previous year and then predict seven days? Should I have a rolling, where it takes the last seven to predict the next seven? Do I do the last three weeks to predict the next seven?"

Those questions are still open, but initial findings showed that neural networks had comparable predictive power to sophisticated time series analysis, Caplice said.

Data Mining and Other New Directions

The Center for Transportation Logistics is exploring several other areas related to how freight transportation markets are structured, Caplice said.

One is the possibility of index-based rates, where rates adjust based on market trend benchmarks. Another is guaranteed contracts, where the carrier provides a lower rate but gets paid whether or not they deliver a particular load.

Electronic logging devices with real-time location data on drivers and loads have downsides but also strong upsides, Caplice said, and shippers are interested in how they can mine that data. There is also the potential to bring ridesharing concepts to freight movement, with more loads sold on the spot than the contract market.

"It's interesting to see what's going to happen," Caplice said. "Will a larger percentage of truckloads move to spot instead of contract if you can ride that market and make it more reliable?"

STEPHEN GOLDSMITH, DIRECTOR, INNOVATIONS IN AMERICAN GOVERNMENT PROGRAM, HARVARD UNIVERSITY

THE FOUR ROLES OF GOVERNMENT IN A NEW MOBILITY OPERATING SYSTEM

September 25, 2018

Watch the video highlights

A new mobility operating system requires government, especially at the city-level, to design transportation around the user—not the mode—according to Stephen Goldsmith, Director of the Innovations in American Government Program at Harvard University's Kennedy School of Government.

Governments pursuing new mobility operating systems will have data-driven protocols, not strict regulations. They will seek rules that make markets work for citizens. And they will give regional planners real authority.

Transportation Meets User Experience

In Indianapolis, where Goldsmith was mayor from 1992 to 2000, the number of taxi medallions was limited by law. But people who needed taxi services most were not getting them, and those who wanted medallions lived in those neighborhoods—but couldn't get them, Goldsmith said.

The issue, in addition to medallion caps, was a transportation system designed around a mode—taxis—instead of a system that promoted cross-modal mobility.

"If we think about the user experience of mobility, if we design a system around the user, that's different than designing a system around the user of a bus, or a taxi, or a transportation network company, or a bike," Goldsmith said. "If we're thinking about a system designed around the omni-channel experience of the user, and if we could come up with that orientation, it would dramatically change things."

Coding the Curb

Curb space used to be a maintenance liability for governments. Today, the curb is valuable, Goldsmith said. But most cities don't know where their signage is, and the curb is not coded to evaluate the cost of using it to drop off from a transportation network company vehicle, or perhaps an automated vehicle.

Los Angeles is one city innovating with curb space through its Code the Curb program. Code the Curb identifies where curb assets are and seeks to use dynamic pricing related to curb use.

"As we think about managing mobility, we also need to think inherently about managing the curb," Goldsmith said. "Not managing parking, but managing the curb."

Making Transportation Markets Work for Residents

The government role over the past 25 years has been to provide transportation, like bus transit, or to regulate transportation, as with taxis. In a new mobility operating system, the government's core responsibility would be equity, to ensure communities are served broadly, fairly, and openly, Goldsmith said.

Data that is real-time, accurate, and comes from multiple sources can help encourage transportation equity. Government can act as a data aggregator that can inform pricing and consumer decisions, Goldsmith said.

"One of the things we need to consider in this new government role is, what information should government require from a commercial operator in its jurisdiction as a condition to use its easements and streets?" Goldsmith said. "What's in real-time? What's not in real-time? What formats? How is privacy handled? How is anonymity handled? And we need to get there. Sometimes it will be relatively easy to negotiate data-sharing agreements, and other situations are more complex."

Regional Planning—With Authority

With enormous amounts of information and the ability to code the curb, government can take a more enlightened approach to managing mobility, Goldsmith said. Government structures, however, may not be up to the challenge. In most places, transit organizations like metropolitan planning organizations (MPOs) are the only regional transportation government bodies, but MPOs may not have the authority to innovate at the city level.

"I would suggest we need to think about new governance structures," Goldsmith said. "We need to think about regional governance and more authority for the MPOs, we need to think about what the platform looks like. Volpe is a terrific place to suggest what the protocols and analytics should look like in those platforms."

KYLE VOGT, FOUNDER AND CEO, CRUISE AUTOMATION
U.S. DOT UNDER SECRETARY OF TRANSPORTATION FOR POLICY DEREK KAN

ARTIFICIAL INTELLIGENCE IN TRANSPORTATION: A CONVERSATION

October 4, 2018

Watch the video highlights

Kyle Vogt, founder and CEO of Cruise Automation, and Derek Kan, U.S. DOT Under Secretary of Transportation for Policy, discussed how automated vehicles fit into current transportation systems, and how vehicle automation is a lot like NASA's Apollo program. The following conversation has been edited for clarity and length.

Under Secretary Kan: Kyle started his career just down the street at MIT (Massachusetts Institute of Technology). MIT does a lot of brilliant things, probably most notably tech development. Given all the things you've done in your career, walk us through some of the big challenges in autonomous vehicle (AV) technology development.

Kyle Vogt: I'll be the first to say this is a really, really hard problem. This is one of the first really great applied artificial intelligence problems. It's become clear that building a prototype autonomous vehicle is something that 5 or 10 talented engineers can do in a few months.

What is becoming apparent now is that the difference between a prototype that can drive around the block once and not hit something, and a commercial product that people can entrust their safety to, is enormous. It's several orders of magnitude more complex, it takes more time to design, develop, to validate and to collect data on, and so there are immense challenges.

Under Secretary Kan: As everybody here knows, transportation is one of the keys to a vibrant economy. The sector itself is incredible. So how do AVs fit into the broader transportation system?

Vogt: First off, transportation is huge: 3.2 trillion miles traveled in a year. If you look at what AVs could do to that, we can look at the rideshare industry as a proxy for what it might become. Rideshare companies today drive less than 1 percent of those 3.2 trillion miles traveled, so everything you think about rideshare, that's just the tip of the iceberg in terms of having an impact on transportation.

AVs have the potential to lower the cost of transportation like in rideshare, to the point where a lot of people are going to flip from owning a car and all the burden that comes with that to using a shared autonomous vehicle on a rideshare network. It's going to make sense economically, it's going to be safer, more convenient, it's going to give you that time back that you spend on your commute.

Under Secretary Kan: What areas of research and development should be done either in the application, development, or testing and deployment of AV technology?

Vogt: The things that are underexploited today are the things that come a little further into the future. There's a lot of focus right now on sensor processing and the first versions of self-driving car systems. What there isn't as much of is thinking about vehicles at a fleet scale. Not just building the first self-driving car, but what happens when you have hundreds or thousands of these in a city and they're all sharing information? Can they look around corners? How can they coordinate to do things like reducing congestion, or even acting as infrastructure for one another?

Under Secretary Kan: You mentioned that AVs are perhaps the best application of AI. Help us unpack that a little bit. You talked about sensing, but why is today unique and what is the arc of AI today that makes this time special?

Vogt: Engineers love to work on AI problems because there are some promising results and there is a lot of innovation in the field right now. What's happening with AVs now is because there is a huge market opportunity and because there is a huge social impact on improving safety. In our case we're using electric vehicles so it's a cleaner form of transportation. All of those things are motivating more people to enter the space and work on these problems. What I meant was this is one of the most impactful applied AI problems you can do today.

People coming out of graduate programs and getting degrees now have a place to go where they can take that academic curiosity and fascination and apply it to a problem that has perhaps one of the largest impacts of any engineering work being done today. That's a powerful combination. This only happens maybe once every ten years or several decades where you have this convergence of high social impact, deeply challenging technology problems, and big market opportunity. When those three things come together it creates something really special. I see self-driving cars today as the Apollo program of this generation.

KIRK STEUDLE, FORMER DIRECTOR, MICHIGAN DEPARTMENT OF TRANSPORTATION

TRANSFORMATIONAL TECHNOLOGIES: A STATE GOVERNMENT PERSPECTIVE

October 22, 2018

Watch the video highlights

Before the traffic signal, a busy intersection could easily become a tangle of pedestrians, bicyclists, and other vehicles vying for rights of way. The electric traffic signal, introduced in the early 20th century, was the first step in automating traffic flow, and is one of the first examples of automation in transportation.

"Automation has been continuing since that time, and it's going to continue," said Kirk T. Steudle, director of the Michigan Department of Transportation.

Vehicle Automation: Safety First

The primary reason for the explosion of vehicle automation technology over the past few years is not convenience, or efficiency, or novelty.

From a road operations perspective, the reason for vehicle automation is safety, Steudle said. In 2017, 37,133 people died in motor vehicle crashes, and more than 3 million people were injured in motor vehicle crashes in 2016.

"If we know that the technology can save lives, why are we waiting to deploy it?" Steudle said. "We can choose to wait to deploy when we don't have a family member in those numbers. When we have a family member in those numbers, waiting until next year is too long."

Many highly automated functions are available on current vehicles. With adaptive cruise control, for example, radar keeps the vehicle a safe distance from a vehicle that slows down.

But full automation, where a human is not needed to operate or monitor vehicle movement, is many years away, Steudle said.

Balancing the Ideal and the Possible

"It's easy for us in the technology transportation space to think forward," Steudle said. "In my job, and my counterparts across the country, we have to balance what's possible—what's utopia 50 years from now—versus what's possible next year. And how do you manage for the maybe 50 years in the middle?"

More than half of states allow autonomous vehicles on public roads, either by executive order or statute. Michigan is among those trying to limit regulatory hurdles to automated vehicle deployment.

"Michigan law allows for complete operations," Steudle said. "If you can buy a vehicle and get FMVSS [Federal Motor Vehicle Safety Standards] approval, you can take it to the Secretary of State with your insurance certificate, you get a metal plate with white and blue letters, and off you go."

The future of vehicle transportation may be fully automated—but that future isn't happening tomorrow

By 2040, 30 percent of vehicles produced will be automated, Steudle said. That means 70 percent of vehicles produced will likely have highly automated functions, but will also still have a brake pedal and steering wheel.

"We have to understand there is a transition—that as a public agency, we've got to provide infrastructure for both," Steudle said. "This is going to be a difficult time. In the near-term, we still have a transportation network that has to serve those legacy vehicles."

CHRIS URMSON, CO-FOUNDER AND CEO, AURORA

DELIVERING THE BENEFITS OF SELF-DRIVING TECHNOLOGY

SAFELY, QUICKLY, AND BROADLY

October 25, 2018

Watch the video highlights

Three things that drivers do: accelerate, brake, and steer. Three things drivers don't do: take naps, write novels, catch up on work, or anything that takes time and doesn't involve driving.

But self-driving cars could free up two weeks every year for the average driver, according to Chris Urmson, co-founder and CEO of Aurora, who delivered the final talk in the U.S. DOT Volpe Center's Transportation in the Age of Artificial Intelligence and Predictive Analytics speaker series.

If cars drove themselves, they wouldn't just give commuters back time. They could vastly improve mobility options for people with disabilities, and they could save thousands of lives.

"We think about the opportunity to save 140 lives a day," Urmson said. "We think about the fact that 6 million people don't have access to transportation that they should, and by bringing this technology to market we can enable them to have the mobility that we all take for granted."

The Driver and the Rider: Two Directions for Self-Driving Vehicles

Current levels of vehicle automation require that people be alert and in charge of driving. The future of self-driving vehicles may continue to follow this path, with drivers ultimately responsible for safe vehicle operation.

Or, the future may be one of widespread, high-level vehicle automation, where the driver becomes a rider, Urmson said.

"There's profound opportunities for change by getting the technology to the point where you can sit back and it's really the technology getting you where you want to go on your day," Urmson said. "We think about that as riding in the vehicles."

Automation Could Bring Big Cost Savings

According to Urmson's "cocktail napkin math," a ride with a transportation network company costs about $1.60 per mile. That's 60 cents for the vehicle and a dollar for the driver. A vehicle operating at a high level of automation would bring today's dollar cost for the driver down to 10 cents per mile—and with three trillion miles of road in the United States, that could mean big aggregate cost savings.

"That's a $300 billion economic opportunity," Urmson said. "This is really the direction this technology is going to push."

Success for Self-Driving Cars Comes Down To Improving Mobility and Safety

The brother of the best man at Urmson's wedding was in his early 20s when he was paralyzed. He was driving in northern Canada and hit a moose. If vehicle automation had existed, that accident might never have happened, Urmson said.

"He's had an incredible career," Urmson said. "He's been in politics, he was a cabinet minister in Canada, but throughout that time he has had to rely on others to get around. He never had privacy in transportation. It's never been on-demand the way you or I would take it for granted. So, giving someone like him the mobility and access that we have is just incredible."

STAKEHOLDER ENGAGEMENT DATA

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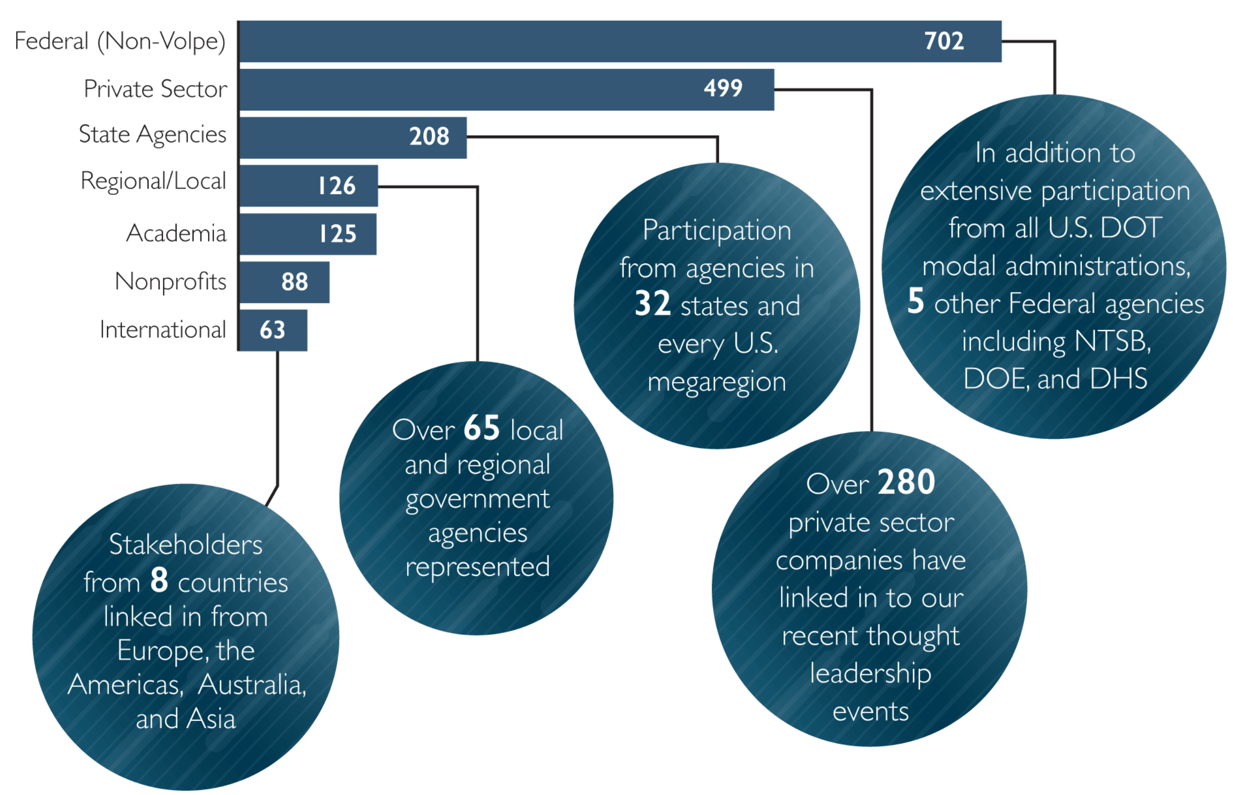

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