



Autonomous trucks lead the way

Many companies are shifting focus from R&D to making driverless models work at scale

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Introduction

AUTO VISIONARIES' DEPICTION of the city streets of 2021, full of self-driving cars seamlessly communicating while passengers worked and/or dozed, was always a bit optimistic. As the technological hurdles have become clearer—and higher—companies and urban planners have pushed back their timelines and toned down their adjectives.¹

But the promise of autonomous vehicles (AVs) is already coming to fruition—in trucking, the often-underappreciated network of tractor-trailers across the country. Look around the room you're in: If you are in the United States, nearly everything around you—from furniture and electronics, to food, to clothing and toiletries—was on a truck at some point. For many Americans, this reality became increasingly apparent in 2020, when the COVID-19 pandemic disrupted supply chains, leaving shelves bare of food and other necessities. Industry insiders have been aware of driver shortages for years,² but the pandemic made the need plain.

In recent years, AV players have increasingly shifted their attention to trucking, specifically Class 8 tractor-trailers, sometimes reallocating capital from other efforts such as robo-taxis.³

Eight startups have raised a collective US\$1.4 billion for self-driving trucking initiatives.⁴

“The Aurora Driver was designed to operate a wide range of vehicles across a variety of use cases. Its path to market starts where it can make the largest impact the fastest. Trucking is that market for a host of technical and economic reasons. From there, our Driver will rapidly expand into delivery and mobility services.”

— Sterling Anderson, Aurora⁵

And this investment appears to be paying off: More companies are deploying autonomous trucks on public roads (figure 1),⁶ well on their way to commercialization. While some of these routes are still for demonstration purposes only, others are regular revenue-generating runs with paying shippers. Granted, all these trucks currently have safety drivers on board, but shippers' willingness to entrust their cargo and logistics networks—and the safety of fellow road users—to autonomous technology speaks to market confidence.

Two factors—one technological, one financial—are putting the spotlight on autonomous trucking.



FIGURE 1

Where self-driving trucks are on the road—and where they're heading

Route type
■ Revenue run route
■ Pilot route



Source: Deloitte analysis based on multiple press reports. See endnote 6 for additional details.

Increased technical feasibility through transfer hub model

While some companies continue to explore the point-to-point model—a self-driving truck traveling from origin to destination without human intervention—many in the industry are increasingly focused on a model that simplifies the technical and operational challenges of autonomous driving. A unique operating model built around transfer hubs (figure 2) can limit variables and minimize the challenges of deploying self-driving vehicles in congested urban environments or complicated distribution center lots. In this model, long-range trucks are driven by humans from their origin point to a dedicated space near an interstate on-ramp before taking off down the highway in autonomous mode. Near the destination, the truck would navigate to a

transfer facility near an offramp, where a human driver would take over for the final surface-street driving on local roads. This model is designed to keep humans in charge of local driving and cargo loading and delivery, while enabling AV fleet operators to focus on operating trucks in a more controlled interstate highway environment.

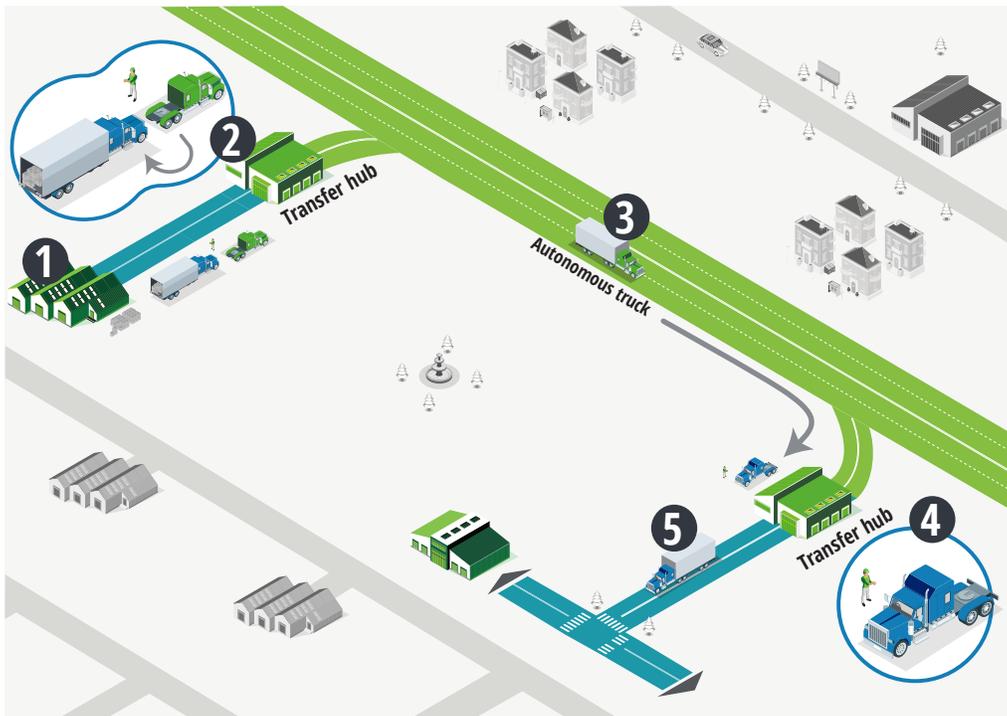
Many companies are also exploring trailer swapping as part of the transfer hub model. In that variation, the trailer is moved from an autonomous tractor unit to a separate human-driven tractor at the transfer hub. This would have the added benefit of allowing the autonomous tractor unit (which would include custom technology and design) to immediately connect to another trailer and stay utilized. The downside would be the operational complexity and time required to swap tractor units compared with the simplicity of having a human drive the autonomous tractor in manual mode.

FIGURE 2

Transfer hub operating model

■ Human-driven route ■ Autonomous route

- 1** **Human** drives truck from distribution center to **transfer hub**.
- 2** **Human** switches trailer to autonomous power rig.
- 3** The **autonomous truck** exits transfer station, onto highway to drive highway portion of run.
- 4** The autonomous truck exits highway and pulls into **transfer hub** at final location. Trailer is switched to human operated power rig.
- 5** **Human** exits transfer hub and drives vehicle to end destination.



Source: Deloitte analysis.

TRANSFER HUBS COULD ACCELERATE THE PATH TO COMMERCIALIZATION

While most autonomous trucking companies have thus far seen transfer hubs as critical to initial commercialization, there is no industry consensus on whether transfer hubs will be needed in the long term. If autonomous tech evolves to enable the point-to-point model, a carrier could potentially eliminate the time and complexity of visiting a transfer hub—and realize additional cost savings from automating the entire trip.

This topic highlights an industry debate around two questions, one technical and one operational:

Can the self-driving technology developed for highway driving and transfer hub navigation be expanded to general surface-street driving over time?

Some see highway driving as a very different technical problem to solve than navigating complex surface streets. Others, particularly those who have invested heavily in self-driving technology for passenger vehicles, argue that many surface street driving learnings and technologies can translate to highway driving, meaning that transfer hubs may be necessary only until street-driving capabilities improve. These two approaches involve developing technologies for fundamentally different operational design domains. And still others are skeptical of destinations and origins being equipped to properly receive autonomous trucks anytime soon, requiring human drivers for the last mile regardless of the autonomous vehicle's capabilities.

How much time, complexity, and cost would hub-based transfers add?

Perspectives on this question vary significantly based on each company's long-term ambitions. Those that anticipate sticking with transfer hubs for the long term are already optimizing their onsite operations for efficiency. Others that see transfer hubs as only an initial step are convinced that the additional operational complexity of transitioning from autonomous to manual and back will add substantial friction.⁷

While transfer hubs are generally expected to hold the majority of trips in the foreseeable future for speed of deployment, both models are expected to coexist in the future when sufficient point-to-point technology is developed. Investors betting on transfer hubs should focus on evolving to meet the longer-term demand.

Clarity of business value

There is a clear-cut business case for adoption of autonomous technology in goods movement, an industry that historically struggles with driver retention. Self-driving trucks offer sizable economic and operational benefits for companies across the supply chain; most notable is a projected 30% or more per-mile cost reduction as compared to the current human-driven truck model.⁸ The savings could be achieved through decreased labor costs, enhanced driving times and range, improved fuel

efficiency, and better safety performance of an automated driving system—and would likely exceed the incremental cost of an autonomous system and transfer hubs. Self-driving trucks could also realize a sizable productivity gain and increase system capacity by being able to operate nearly 24/7 without restrictions on daily driving time—doubling their daily range, from 600 to 1,200 miles.⁹ This would increase delivery capacity significantly without increasing fleet sizes and help to address the growing demand for faster and more predictable shipping.



CREATING A JUST TRANSITION FOR DRIVERS

The emergence of this new technology and business model has sparked concerns around potential job loss for hundreds of thousands of drivers.¹⁰ Yet companies have an opportunity to manage this transition with humanity, justice, and forethought.

Freight movement is rapidly increasing, anticipated to rise from 17.4 billion tons in 2015 to 25.5 billion tons in 2045, with the trucking industry moving the vast majority of those tons.¹¹ Accommodating this growth will place tremendous pressure on every component of the trucking industry, including its already-strained workforce. Since the 1980s, the industry has experienced high voluntary turnover, the highest of which is in the long-distance driver pool.¹² Much of the turnover is attributable to low wages, an aging workforce, and deleterious health effects associated with long-haul driving. Those challenges seem to be manifesting in the industry's compliance and safety record, with numerous hours-of-service violations¹³ and crashes involving large trucks ticking up in recent years, though they remain low by historical standards.¹⁴ Absent significant changes to its business model and talent pool, the trucking industry will be challenged to address the growing shortage of drivers, estimated to hit 160,000 drivers by 2028,¹⁵ and still meet rising demand, a trend that has been exacerbated by the COVID-19 pandemic.

The advent of autonomous technology could gradually improve or eliminate many of these labor issues; since the shift to driverless will likely play out over decades, companies could look to avoid layoffs by allowing aging drivers to retire and be "backfilled" by an autonomous system. The transfer hub model would let drivers focus on the more-involved first and last legs of a haul, in which drivers today perform many nondriving tasks such as communicating with customers, loading and unloading, and coupling tractors and trailers.¹⁶ Additionally, this model can allow drivers to spend less time away from home. This could create new dedicated first- and last-mile jobs, but also concern that those jobs might be classified as independent-contractor jobs and come with low wages and poor conditions.¹⁷

There may be additional opportunities for new and expanded responsibilities for the types of jobs potentially needed to manage, operate, and maintain fleets of autonomous trucks. For example, "fleet monitors" working at a central hub would need to understand how to use tracking systems, dynamic routing, and AV technologies to ensure that vehicles on the road are operating smoothly. Inspectors and even law enforcement would need to be aware of the new technology and understand the state and federal regulations governing the new technology. Mechanics, who work for carriers or repair shops, would need to learn how to perform repairs on increasingly sophisticated autonomous operating systems. These higher-skilled jobs could offer an opportunity for increased wages. Workforce education and training, as part of a holistic response, would be key.¹⁸

Employers and agencies should look to actively manage the transition to mitigate negative impacts on today's and tomorrow's truckers. Trucking companies should consider dedicating some of the significant cost savings they will likely enjoy from automation by investing in job training to help staff the new, higher-skilled technical roles from their existing driver pool.

Where might autonomous trucking be available first, and how would it proliferate?

GIVEN THE SIZE of the opportunity, many shippers and fleets are asking, “When will autonomous trucking be available?” We believe the more important question to ask is, “Where might autonomous trucking be available first, and how would it proliferate?” Unlike software or a new product, autonomous trucking will have no clear launch date. Instead, it will likely be deployed across certain geographies over time as self-driving companies learn and test new routes, building out their lane-level service networks over years. The sequence and rate at which this happens will likely be driven by a complex interplay between technological, economic, and regulatory incentives and limitations as well as companies’ willingness to reassess entrenched operations and footprint.

Deloitte has developed a scenario planning model that aims to capture this complex interplay and use it to try to predict the expansion of autonomous trucking adoption at a lane level across the United States. Specifically, the model tries to predict which lanes (for example, Los Angeles to Dallas, Atlanta to Miami, or Nashville to Chicago) will go live first, second, and third, assuming autonomous trucking companies are aiming to maximize profits (aggregating

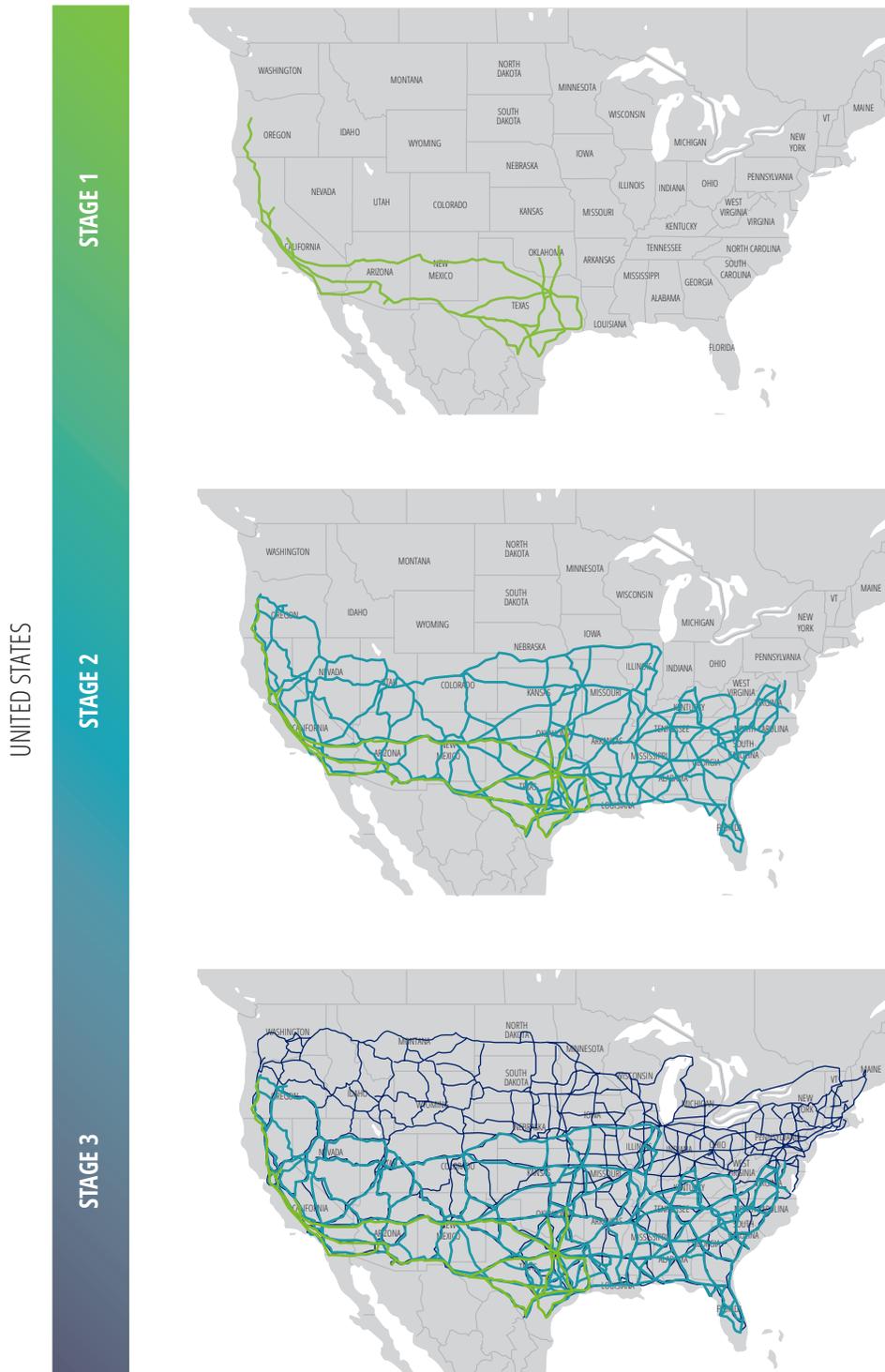
all runs that occur annually on a given lane) while bound by a set of constraints—snow, traffic congestion, roadway quality, current regulation, state-level business friendliness, and more.¹⁹

Unlike software or a new product, autonomous trucking will have no clear launch date. Instead, it will likely be deployed across certain geographies over time as self-driving companies learn and test new routes, building out their lane-level service networks over years.

Our model predicts that autonomous truck technology will likely be first commercialized in the Southwest—specifically, Texas, Arizona, and New Mexico, followed quickly by Oklahoma. Favorable regulation, weather, and road conditions seem to make the area a natural choice for scaled rollouts.

FIGURE 3

Deloitte Autonomous Truck Adoption tool



Source: Deloitte analysis.

"In 2018, we identified Texas as the ideal location to start commercializing our autonomous trucks because of the dry weather, massive freight economy, strong highway infrastructure, innovation-friendly regulations, and public-private partnership potential. It's why our first route was Dallas-Houston in 2019. As we continue to commercialize, we continue to be even more convinced that Texas is the right place to start."

— Don Burnette, Kodiak²⁰

Industry players are less certain about the next region to adopt the technology. Based on the ROI and volume of freight traveling on high-traffic corridors in close proximity to the first autonomous zones, our model predicts that California and Oregon could adopt the technology next, though some companies argue that Florida might be better positioned for testing and deployment, and therefore the Interstate 10 corridor across the Southeast should open before the West Coast.

As the technology matures, autonomous trucking is expected to steadily move north, continuing to open new shipping lanes. At least 37% of shipping revenue passes through Illinois to Pennsylvania today,²¹ and overcoming the weather and congestion challenges of this passage could dramatically accelerate adoption overall.

Within each zone, there are many forces that could accelerate or delay the adoption of autonomous trucks, including technology development, privacy and security, and investor appetite for risk. For example, if companies are able to quickly develop technology for driving in inclement weather, many routes could open for autonomous trucking faster than expected. Conversely, if public resistance to autonomous trucking increases and regulations are more stringent, adoption may slow and focus on the country's least populated routes.

Under the transfer hub model, a significant portion of high-frequency, shorter-mileage shipments may not be automated even once the lanes open. The rationale behind this would likely be primarily economic, balancing the savings from the autonomous middle mile with the cost of the manually driven portions. In fact, Deloitte's model estimates that about three-quarters of the trucking miles driven could be automated via the transfer hub model, but this would account for only a third of the annual loads shipped. Even with these assumptions, the market is huge: At current prices, the model predicts, the annual value of automated shipping could exceed US\$300 billion.²² If and when point-to-point operations roll out at scale, this may grow significantly as shorter routes come on board.

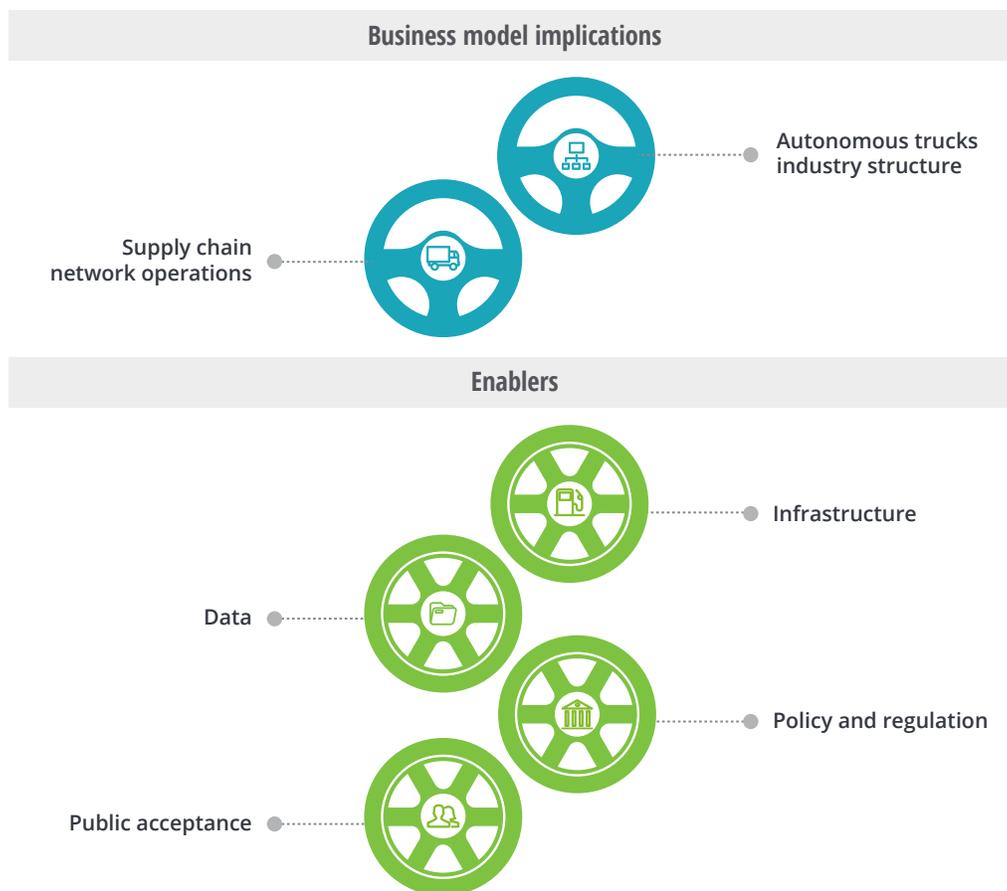
Ecosystem impacts from autonomous trucking

IMPORTANT QUESTIONS REMAIN around the implications of autonomous trucks and how enabling ecosystems would need to evolve to support the new technology. While this list is hardly

exhaustive—it doesn't include topics such as how insurers could cover autonomous trucks and their cargo—it does focus on many important areas.

FIGURE 4

Autonomous trucks industry structure



Source: Deloitte analysis.

Autonomous trucks industry structure

As autonomous technology increases the complexities of operating a fleet while simultaneously lowering the cost, how can technology providers, original equipment manufacturers (OEMs), fleets, and shippers move up and down the value chain in order to capture a portion of the new profit pool? What new services, companies, and workforce needs might emerge as the ecosystem changes?

Three distinct business models are beginning to emerge in the market, sitting along a spectrum with varying levels of integration (figure 5). With **autonomous software-as-a-service**, the startup sells directly to, or collaborates with, OEMs to get to the fleets. This is similar to the way in which telematics solutions are sold today and would include limited or no implementation support. A more **holistic solution** goes a step further, with startups setting up and managing the maintenance and operational partnerships to support the fleets' implementation. This operational support can be provided by the

FIGURE 5
Autonomous truck startup business models

✔ Autonomous trucking startup
 ✔ Customer
 ✔ Partnership opportunities

	← Autonomous Software-as-a-Service	Holistic solution	Fleet operator →
	Autonomous trucking startup sells tech through OEM channels but is focused on hardware and software	Startup sells full trucks through OEM channels and provides operational support to carriers	Startup operates as a carrier, transporting loads for shippers
OEM	✔	✔	✔
Autonomous technology	✔	✔	✔
Autonomous truck infrastructure	✔	✔	✔
Maintenance	✔	✔	✔
Carrier/fleet	✔	✔	✔
Broker	✔	✔	✔
Shipper	✔	✔	✔



Source: Deloitte analysis.

autonomous company directly or through an ecosystem of partnerships. Finally, the **fleet operator** model has startups acting as the carrier and working directly with shippers to move goods.

While there is significant value to be captured from self-driving technologies, it remains to be seen which players will capture this value and how these different business models could influence that. For example, as the industry evolves and shifts to greater proportions of autonomy—and as the capital required and operational complexity of running long-haul increases—fleet consolidation is expected, as smaller fleets get cut out of the market. Given that 84% of fleets have six or fewer tractor units, this would be a dramatic change.²³

Leaders looking to work with autonomous truck technology developers should understand these three different business models and what each would mean for their operations, their required partnerships, and potential economic impacts.

Supply chain network operations and optimization

How would a 30% decrease in cost, doubling of daily driving range, and near 24/7 trucking operations affect decisions such as optimal warehouse placement, mode choice optimization (for example, air and rail substitution), and hours of operation for warehouse staff?

For shippers, autonomous trucks can greatly change the dynamics of the supply chain. Today, shippers face the challenge of high cost of truckload transportation due to the lack of capacity compared to available loads. Autonomous trucking could drive down prices by reducing costs, thus making shippers more inclined to select trucking

over rail. Lead times could also decline due to longer hours of operation, making trucking a viable alternative to costly air freight. Perishable goods could especially benefit from decreasing transit times. Furthermore, AV technology could simplify the journey from manufacturing site to consumption destination, eliminating a significant amount of the touches that today add time, money, and effort. Shippers should begin to plan for these changes early—the mode selection shifts may happen quickly.

Shippers should also reconsider their facility network. As autonomous technology rolls out, distribution modeling will likely show that current networks—especially if they are hub-and-spoke—may no longer be efficient. Take, for example, distributors: To reduce transportation costs, distributors have been expanding their footprint, at the expense of redundant inventory and increased warehousing costs, to be within a one-day round trip to their customers. Autonomous trucks can dramatically increase the distance of a one-day transit because the driver is not constrained to hours of service. This means the distributor would need fewer facilities and lower inventory. Theoretically, with a daily driving range of more than 1,000 miles and a nationwide transfer hub network, a shipper could reach any point in the contiguous United States within 24 hours with only a few distribution centers.²⁴ It also could mean facilities need to be made bigger and incorporate multishift, all-night shipping and receiving.

Because of long lease times for facilities, and extensive planning needed for network optimization, shippers should start planning for autonomous shipping well before the technology reaches their network. Investments in warehouse spaces and decisions about shipping providers should be carefully considered so that adjustments

can be made as autonomous technology progresses. As technology along the entire supply chain evolves, there could also be new opportunities to optimize by connecting autonomous trucks with other innovations such as “lights-out warehouses,” which operate with no humans present.

Infrastructure

As tech companies begin to commercialize self-driving trucks, how should they and their fleet partners leverage ecosystem players such as real estate companies, truck stop operators, and telecoms, to efficiently access and upgrade infrastructure such as transfer hubs, remote maintenance, and 5G connectivity?

Although the rollout of autonomous trucks is expected to happen over an extended period, large-scale capital decisions for physical and digital infrastructure investment can't wait to take these considerations into account. A number of industries are currently positioned to offer the services and infrastructure that autonomous trucks will likely need. Existing trucking support networks such as truck stops, repair networks, OEM dealers, and state rest stops could all be converted to handle different needs. Businesses such as shopping malls or big-box retailers with substantial land footprints—particularly near highways—could convert some of their parking space to transfer hub space. Finally, smaller players that specialize in a service such as data transfer or on-demand maintenance could combine to offer more comprehensive solutions. It remains to be seen how this ecosystem will form and what types of partnerships might be required to keep autonomous trucks on the road, but the earlier that companies can begin to form partnerships and shape offerings, the more likely they are to play a central role in the ecosystem as it scales.

Data

With the driver less critical for the highway journey, what data integration and management will be necessary between autonomous trucks, shippers, brokers, infrastructure players, and governments to ensure efficient and safe operations? Who will own the data and the integration platforms? Who will consume the data?

Autonomous trucking is expected to drive a fundamental shift in how data gets looked at and treated in an enterprise. Behind a truck's autonomous driving system is software and compute power processing massive amounts of data from cameras, lidar, and radar. This data is essential in enabling a vehicle's safe operations and decision-making. But sensors can also generate additional types of information, such as location data, that would be critical for the broader ecosystem. Many stakeholders would depend on data integration to complete typical day-to-day functions without a driver. To meet government regulations for fuel tax collection,²⁵ for instance, the autonomous truck fleet would need to keep track of mileage and fuel purchases accrued in each state. Fueling and maintenance by outside parties would require platform integration to schedule and pay for services.

The data collected from AV systems could also unlock new opportunities for consumers—and could serve as an enhanced input to transportation management systems for more sophisticated route, load, and carrier scheduling optimization, as well as real-time tracking and visibility. Autonomous systems providers and fleets utilizing autonomous trucks should consider how real-time data around construction, traffic, road, and weather conditions can be used to improve their own fleet operations and/or monetized to outside organizations by providing fresh visibility into highway routes. In addition to AV-specific data, the advancement of

connected trucks can provide machine performance data to inform predictive maintenance and manufacturing quality control.

Data access, quality, and security are considered the major challenges in unlocking these opportunities, securing partnerships, and integrating across disparate processes and management systems. Stakeholders should act now to build the robust infrastructure to maximize their potential benefits from data platform integration and begin conversations with others about shared data standards and interoperability.

Policy and regulation

How will the federal, state, and local regulatory landscape affect autonomous trucking adoption nationwide?

In the last few years, the Energy and Commerce Committee and the U.S. Senate Committee on Commerce, Science, and Transportation developed wide-ranging bills addressing many facets of AV policy, but much is left unresolved. One challenge for federal regulators in this area is the question of jurisdiction: Since AV technology doesn't fit neatly into any single domain in Washington's mosaic of agencies, it is likely that implementation of legislation focused on automation, or adjacent issues such as 5G and closing the digital divide, would touch multiple large federal agencies such as the U.S. Department of Transportation (DOT), the Federal Communications Commission, and possibly the U.S. Department of Agriculture.

Without a clear, guiding federal strategy (legislative or regulatory), states have taken steps to revise their own regulatory frameworks to address AV-related topics, resulting in a patchwork of rules and a lack of clarity. Thus far, the DOT has taken a nonregulatory approach to AVs, offering stakeholders voluntary

guidance to promote innovation. Though this nonbinding solution offers flexibility while the technology continues to rapidly evolve, it has led to a patchwork regulatory environment with different interpretations and ambiguity, introducing challenges for autonomous trucking innovators and manufacturers when they attempt to scale nationwide. Nevertheless, there is optimism Congress has laid the groundwork for AV-related legislation—including broadband and 5G—and that the DOT will build on regulatory actions taken in 2020 to support economic recovery and job creation post-COVID-19.²⁶

Two DOT modal agencies with jurisdiction over autonomous trucking, the National Highway Traffic Administration and Federal Motor Carrier Safety Administration, have taken important steps, issuing advance notices of proposed rulemaking—focused on identifying regulatory barriers to AV innovation and adoption, as well as safety principles for defining and assessing autonomous driving system competence—which indicate that regulatory action may be coming shortly.²⁷ Writing and issuing regulations is often a yearslong process, and these broad, early regulatory actions, coupled with ongoing research and analysis, could position the new Biden administration to move forward with regulatory action more quickly. As agencies continue their rulemaking processes, industry players can engage with the DOT to help inform these rules by responding to requests for public comment, participating in public listening sessions, and engaging with new agency leadership.

Additionally, as the 117th US Congress takes office, signals indicate that legislating around AVs will continue to be a priority in the House of Representatives.²⁸ As lawmakers begin setting the policy agenda, ecosystem players have opportunities to educate lawmakers on progress—as well as the safety and economic benefits that these new technologies offer—to ultimately help shape legislation.

Public acceptance

How might public perception of AV technology affect adoption, and what actions can ecosystem players take to educate the public?

Among the main motivations for deploying autonomous technology in vehicles is to increase vehicle safety. As autonomous trucking becomes more visible, public perception of AV technology safety will influence acceptance and adoption—and can serve as either an accelerator or barrier. Both federal regulators and industry players recognize public acceptance of AV systems as a key component of broad public adoption of this technology²⁹ and are making efforts to educate the public. In fact, industry players have launched a coalition with the express purpose of “informing the public about automated vehicles and their potential.”³⁰

Recent polling data, however, shows that the American public remains wary of AVs: More than half of surveyed Americans are concerned about the idea of AVs even being tested near where they live.³¹ Reports of traffic incidents involving AVs have had a significant and lasting impact on consumers’ view

of the technology, regardless of fault: Public trust in self-driving cars quickly fell after a few high-profile incidents in 2018.³² But familiarity should help—several studies have shown that individuals who have interacted with AVs are more likely to have positive attitudes toward the technology.³³

For this reason, the disruption of COVID-19 to supply chains worldwide may accelerate public acceptance of autonomous driving systems, due to increased public exposure to automation through delivery robots and autonomous taxis. During the pandemic, the public need for “contactless” delivery has accelerated demand for—and public exposure to—autonomous delivery robots and vehicles as these companies have partnered with major grocery stores, retailers, and restaurant chains to deliver essential goods.³⁴ Recent research suggests that this exposure, and continuing COVID-19 concerns, have made Americans increasingly comfortable with delivery automation.³⁵ Industry players should continue to prioritize education and outreach efforts, and to increase public exposure to AV technologies, while maintaining vigorous safety standards—bearing in mind that a single high-profile incident could seriously damage public acceptance.

Conclusion

THE COVID-19 PANDEMIC has made clear the national economy's dependence on trucking. From paper towels and pinto beans to ventilators and vaccines, the lifeblood of American commerce and, increasingly, health, lies in the millions of 18-wheelers traversing this country's highways.

Autonomous trucks could lead to the most fundamental reshaping of that system since the building of the interstate highway network in the middle of the last century. The potential shift presents tremendous challenges as well as opportunities for players at every stage of the value chain. And those that prepare for that future now—including by planning for a just and fulfilling future for drivers—have a chance to remake one of the foundations of the American economy.



Endnotes

1. Eric Adams, "Why we're still years away from having self-driving cars," *Vox*, September 25, 2020; Cade Metz and Erin Griffith, "This was supposed to be the year driverless cars went mainstream," *New York Times*, May 12, 2020; Roberto Baldwin, "Self-driving cars are taking longer to build than everyone thought," *Car and Driver*, May 10, 2020.
2. Bob Costello and Alan Karickhoff, "Truck driver shortage analysis 2019," American Trucking Associations, July 2019.
3. Keith Naughton, "Waymo CEO sees driverless trucking catching on faster than taxis," *Transportation Topics*, October 29, 2019.
4. Some US\$80 billion invested in autonomous vehicles or related core technologies between August 2014 and June 2017: Cameron F. Kerry and Jack Karsten, "Gauging investment in self-driving cars," Brookings, October 16, 2017; Amir Efrati, "Money pit: Self-driving cars' \$16 billion cash burn," *The Information*, February 5, 2020; Crunchbase shows substantial amounts raised by Waymo, TuSimple, Kodiak Robotics, Plus.ai, Embark, Aurora, and Ike.
5. Deloitte conversation with Aurora leadership, December 2020
6. Alex Davies, "Self-driving trucks are now delivering refrigerators," *Wired*, November 13, 2017; Stephen Edelstein, "Embark semi-autonomous truck drives from California to Florida," *The Drive*, February 7, 2018; Murray Slovick, "TuSimple completes self-driving truck test for the USPS," *ElectronicDesign*, June 24, 2019; Orla McCaffrey, "Self-driving trucks are cruising down I-45 between Dallas and Houston," *Dallas Morning News*, August 6, 2019; UPS, "UPS invests in autonomous trucking company, tests self-driving tractor trailers," August 15, 2019; Jon Fingas, "Daimler starts testing self-driving trucks on public roads," *Engadget*, September 9, 2019; Kirsten Korosec, "TuSimple adds another \$120 million to its self-driving trucks war chest," *TechCrunch*, September 17, 2019; Alan Ohnsman, "Self-driving startup Embark raises \$70 million, opens freight transfer hubs for robot big rigs," *Forbes*, September 25, 2019; Plus.ai, "Plus.ai completes first cross-country commercial freight run by a self-driving truck in record three days," *Business Wire*, December 10, 2019; Chris Woodyard, "Self-driving big-rig trucks coming soon? Waymo set to begin mapping interstates in Texas, New Mexico," *USA Today*, January 23, 2020; David Wichner, "TuSimple expands self-driving truck pilot with shipper UPS," *Tucson.com*, June 29, 2020; Aurora, "Moving towards a commercial product, Aurora's vehicles hit Texas roads," *Medium*, July 20, 2020.
7. Deloitte conversations with autonomous truck technology providers, 2020.
8. *An Analysis of the Operational Costs of Trucking: 2019 Update* breaks down marginal carrier costs per mile in 2018 for both vehicle-based and driver-based costs for a total cost per mile of US\$1.821. "A detailed commercialization analysis of autonomous vehicle technology in the trucking industry" estimates the exit-to-exit autonomous leg to cost US\$1.26 per mile, a 30.7% savings. Incorporating additional costs and savings such as the human-driven drayage leg and better fuel efficiency, our analysis shows savings in the 30% range.
9. Currently hours-of-service restriction allows drivers to be on the road for 11 hours a day. Assuming average highway truck speeds of 55–60 mph, this comes out to 605–660 daily miles. An autonomous diesel-powered truck would not be subject to hours of service restriction and could feasibly run 20 hours a day, allowing an average of four hours for loading, fueling, and maintenance activities. The total: 1,100–1,200 miles.
10. Steve Viscelli, *Driverless?: Autonomous trucks and the future of the American trucker*, UC Berkeley Center for Labor Research and Education and Working Partnerships USA, September 2018, p. 4; Maury Gittleman and Kristen Monaco, "Automation isn't about to make truckers obsolete," *Harvard Business Review*, September 18, 2019; Maury Gittleman and Kristen Monaco, "Truck-driving jobs: Are they headed for rapid elimination?," *Industrial and Labor Relations Review* 73, no. 19 (2019).

11. Center for Transportation Analysis, "Freight Analysis Framework Data Tabulation Tool (FAF4)," accessed January 16, 2021.
12. Stephen V. Burks and Kristen Monaco, "Is the U.S. labor market for truck drivers broken?," *Monthly Labor Review*, U.S. Bureau of Labor Statistics, March 2019.
13. American Transportation Research Institute, *Critical issues facing the trucking industry—2016*, October 2016.
14. Federal Motor Carrier Safety Administration, "Large truck and bus crash facts 2015," U.S. Department of Transportation, November 2016.
15. Costello and Karickhoff, "Truck driver shortage analysis 2019."
16. Viscelli, "Driverless?."
17. Ibid, p. 29.
18. John J. Leonard, David A. Mindell, and Erik L. Stayton, "Autonomous vehicles, mobility, and employment policy: The roads ahead," MIT Work of the Future, August 2020.
19. Autonomous truck adoption model combines US Department of Transportation data on current freight movements with market forces (such as cost per mile, existing autonomous investment, and price elasticity) and potential limitations (such as state-level regulations, weather, and traffic). Model outputs were tested with multiple autonomous truck technology providers.
20. Deloitte conversation with Kodiak leadership, December 2020.
21. Based on Deloitte analysis using the US Bureau of Transportation Statistics' "Commodities flow survey."
22. This model is based on filtering to routes that meet certain length and frequency thresholds. Shorter or infrequent routes, which make up a large proportion of the market, are excluded.
23. Owner-Operator Independent Drivers Association, "Trucking facts," accessed January 13, 2021.
24. The contiguous United States has a total of 3.1 million square miles, with a rough width of 2,700 miles and height of 1,600 miles. With an autonomous truck able to drive 1,100–1,200 miles in any direction, two or three distribution centers would be more than adequate to cover the lower 48 states.
25. The International Fuel Tax Agreement states that commercial carriers must keep precise records of fuel purchases, mileage, and fuel taxes accrued in each state or province traveled in. See Michael Garza, "How to meet IFTA requirements," *Keep Truckin*, January 13, 2020.
26. Russell H. Fox et al., "What's new in 5G—December 2020," *National Law Review*, December 3, 2020; National Conference of State Legislatures, "Autonomous vehicles: Self-driving vehicles enacted legislation," February 18, 2020.
27. National Highway Traffic Safety Administration, "Framework for automated driving system safety," November 19, 2020; National Highway Traffic Safety Administration, "U.S. Department of Transportation seeks public comment on automated driving system safety principles," November 19, 2020.
28. David Shepardson, "Congress will try again in 2021 on self-driving car reform," Reuters, September 23, 2020.
29. "U.S. DOT will lead efforts to address potential safety risks and advance the life-saving potential of automation, which will strengthen public confidence in these emerging technologies." U.S. Department of Transportation, *Preparing for the future of transportation: Automated vehicles 3.0*, October 4, 2018.
30. Partners for Automated Vehicle Education, "About," accessed January 13, 2021.
31. Deloitte, *2020 Global Automotive Consumer Study: Is consumer interest in advanced technologies on the move?*, March 2020.

32. Polling data demonstrates the damaging impact of a single incident—Uber’s fatal self-driving car accident in March 2018—on public perceptions. AAA’s surveys report a significant increase in the number of surveyed Americans indicating being afraid to ride in a self-driving car: more than 70% in 2018 and 2019, up from 63% in 2017.
33. Praveena Penmetsa et al., “Perceptions and expectations of autonomous vehicles: A snapshot of vulnerable road user opinion,” *Technological Forecasting and Social Change* 143 (June 2019): pp. 9–13
34. Peter Lyon, “Demand for autonomous delivery robots rises as pandemic continues,” *Forbes*, July 27, 2020; Alan Ohnsman, “Coronavirus scrambles self-driving race, pushing Nuro’s delivery bots to front of the pack,” *Forbes*, July 9, 2020.
35. Consumer Technology Association, “Autonomous delivery systems: Consumer awareness and favorability,” June 2020.

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