Autonomous Trucking Gains Traction

Detailing the autonomous trucking industry's current state and future projections

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Contents

Key takeaways

- In the first half of 2021, investors poured $5.6 billion into autonomous trucking companies such as TuSimple, Plus, and Embark, thus eclipsing the $4.2 billion invested in 2020 and marking a record for the autonomous trucking space.
- The valuation gap between autonomous trucking and robotaxi companies appears to be narrowing as investors recognize the broader and more near-term opportunity in automating logistics.
- We forecast the global market for autonomous trucking will grow from $528.0 million in 2023 to $166.8 billion in 2035.
- Our unit economics analysis illustrates that autonomous driving technology enabling hub-to-hub transportation could reduce the cost of trucking from $1.65 per mile to $1.30 per mile by mid-decade.
- Rather than displacing workers, we believe autonomous trucks will increase transportation capacity, ease supply chain constraints, augment the trucker workforce to meet the labor shortage, reduce transportation costs such as labor and fuel, and reduce collisions.
- Timeline expectations for autonomous truck adoption may be aggressive as the market underestimates the complexities associated with technological development, regulation, and infrastructure.
- We believe autonomous technology could drive consolidation among operators as larger companies will be better positioned to invest in networks supporting autonomous fleets.

Introduction

While the robotaxi industry continues to dominate driverless car narratives, the trucking industry may be the first area to adopt autonomous technologies on a large commercial scale. Relative to the taxi industry, the fragmented trucking industry consists of many small regional and national providers operating various types of shipping services. Some shipping routes—such as long-haul highway trucking—may be well suited to driverless technologies that succeed in controlled environments. And while taxi providers largely view autonomous technology as threatening and thus shun its adoption, large trucking fleets believe self-driving technologies can supplement low-margin operations with higher-margin automated route capabilities—as addressed in our unit economics analysis later in the note.

We estimate the market size for autonomous trucking could experience tremendous growth over the next decade—potentially reaching $166.8 billion by the mid-2030s as some routes go fully autonomous. As our analysis highlights, VC funding for autonomous trucking has been on the rise, and the industry is attracting a broad set of investors, including traditional VC, industry incumbents, and trucking logistics providers. As a result, autonomous trucking startup valuations are climbing more quickly than those of the robotaxi industry.

Autonomous technology is a good fit for the trucking industry

The trucking industry is comprised of a disparate group of original equipment manufacturers (OEMs), suppliers, carriers, and brokers. The OEM market is relatively consolidated, and leading companies include Daimler (ETR: DAI), Navistar, PACCAR (NASDAQ: PCAR), and Volvo (STO: VOLV A). New entrants developing electric trucks include Hyzon Motors, Tesla (NASDAQ: TSLA), Nikola (NASDAQ: NKLA), and Hyliion (NYSE: HYLN). These manufacturers sell their vehicles to operators, which include companies such as Amazon (NASDAQ: AMZN) and Walmart (NYSE: WMT) and for-hire carriers such as XPO Logistics (NYSE: XPO), Knight-Swift Transportation (NYSE: KNX), and J.B. Hunt (NASDAQ: JBHT). Apart from the major carriers, the industry is fragmented, with over 90% of fleets operating six or fewer trucks.[1]

1: “Economics and Industry Data,” American Trucking Associations, n.d.

Trucking ecosystem

OEMs	Electric OEMs	Brokers	Operators	Carriers
Daimler	Hyzon Motors	C.H. Robinson	UPS	XPO Logistics
Navistar	Tesla	Coyote Logistics	FedEx	Knight-Swift Transportation
PACCAR	Nikola	Total Quality Logistics	Amazon	J.B. Hunt
Volvo	Hyliion	Echo Global Logistics	Walmart	

Full-stack vendors	Lidar vendors
Waymo	Velodyne
TuSimple	Hesai
Aurora	Luminar
Plus	Ouster
Embark Trucks	Aeva
Torc Robotics	AEye
Locamation	Insight
Inceptio Technology	
Kodiak	
Einride	
Outrider	
Ike Robotics	
Waabi	

Source: PitchBook | **Geography:** Global

In the current environment, carriers face a host of challenges. Primarily, the ongoing trucker shortage is having ripple effects across the supply chain, with constrained transportation capacity leading to delays and higher freight costs. In addition, rising fuel and insurance costs are pressuring an already structurally low-margin industry.

Autonomous trucking technology could solve many of these challenges by alleviating the labor shortage, improving margins, making trucks safer, and ultimately unlocking capacity in supply chains. Autonomous driving technology providers such as TuSimple (NASDAQ: TSP), Plus, and Embark provide lidar and camera-based perception systems that enable trucks to drive themselves. Although the technology is not yet perfected, it holds significant potential for use in long stretches of highway driving, wherein the labor shortage is most pronounced.

Although autonomous cars and trucks share much of the same technology, we see three crucial differences between the autonomous truck and robotaxi industries: the state of the technology, sources of demand, and providers.

- **Autonomous trucking tech is more mature than robotaxi tech.** We believe the technology for automating trucks is much further along than automating cars, thanks to use case simplicity. Unlike navigating dense urban streets, trucks spend much of their journeys on long, straight, open roads. These environments enable lower success thresholds relative to consumer applications, which should accelerate time to commercialization.

- **Users, not providers, are driving demand.** By and large, passenger autonomous vehicles are a product of OEMs determining which types of technologies will be most successful in the market. Conversely, the needs of fleet operators—who see the technology as a means to improve business models—influence commercial autonomous vehicle production. This heightens demand for the improvement of autonomous trucking technology, whereas suburban robotaxis continue to struggle with product-market fit—as explored in our recent analyst note Robotaxis and the Road to Profitability.

- **Startups dominate autonomous trucking.** While Big Tech and incumbent automakers dominate the autonomous car industry, startups lead the development of autonomous trucking technology. These include Aurora, which was founded by leaders from Google (NASDAQ: GOOGL), Uber (NYSE: UBER), and Tesla's self-driving projects; TuSimple, which publicly listed in April 2021 at a valuation of $8.5 billion; and Plus, which recently received an order for 1,000 autonomous driving systems from Amazon.[2]

Financing trends

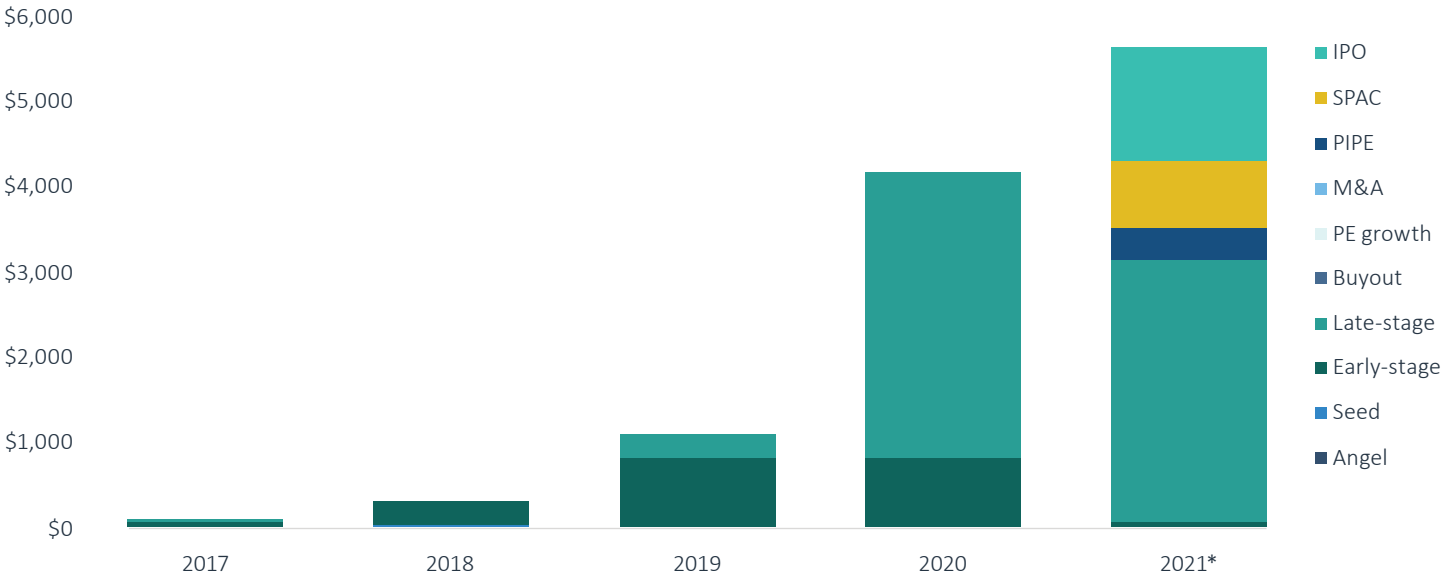
Top 10 autonomous trucking companies by capital raised

Company	Close date	VC raised to date ($M)*	Deal size ($M)	Pre-money valuation ($M)	Post-money valuation ($M)	Deal type
Waymo	June 16, 2021	$5,500.0	$2,500.0	N/A	N/A	Late-stage VC
TuSimple	April 15, 2021	$2,034.2	$1,351.4	$7,406.6	$8,487.7	IPO
Aurora	April 6, 2021	$1,217.5	$54.9	N/A	N/A	Late-stage VC
Plus	May 10, 2021	$1,035.0	$345.0	N/A	$3,300.0	SPAC
Embark Trucks	June 23, 2021	$731.5	$414.0	$4,746.0	$5,160.0	SPAC
Inceptio Technology	November 9, 2020	$230.0	$130.0	N/A	N/A	Series A1
Einride	May 6, 2021	$154.9	$110.0	N/A	N/A	Series B
Outrider	October 28, 2020	$127.3	$65.0	$195.0	$260.0	Series B
Waabi	June 8, 2021	$82.7	$82.7	N/A	N/A	Series A
Ike Robotics	February 5, 2019	$54.5	$52.0	$200.0	$250.0	Series A

Source: PitchBook | **Geography:** Global
*As of June 25, 2021

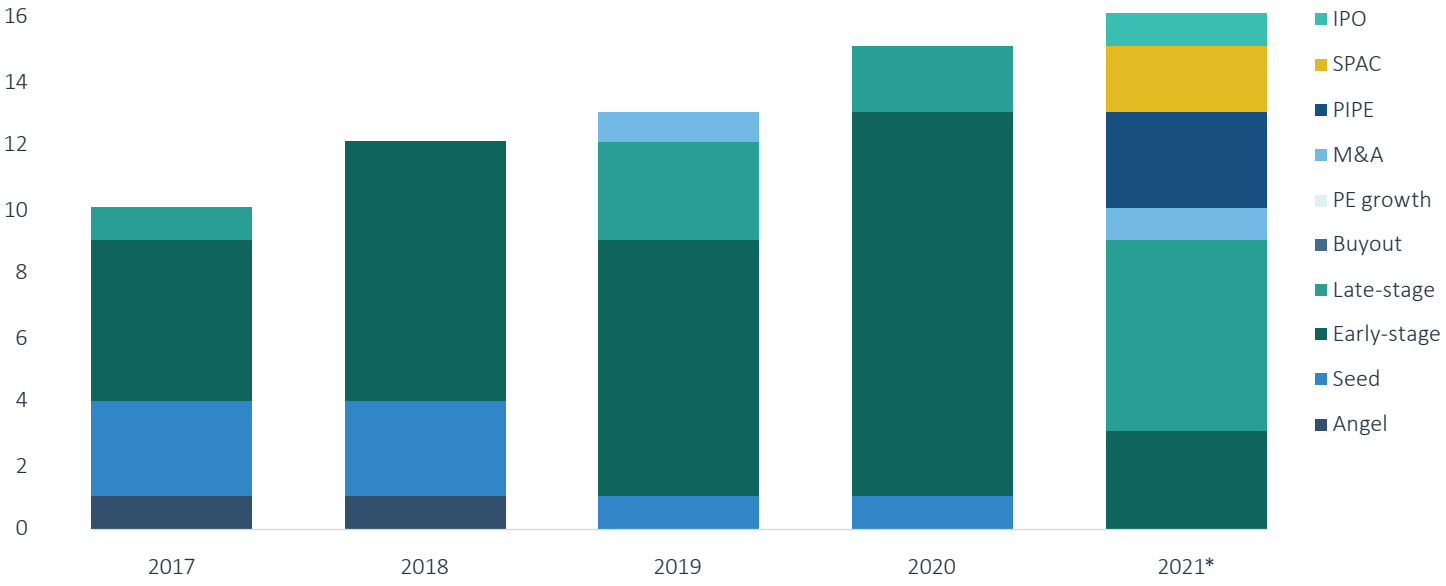
2: "Amazon Snaps Up Option to Buy Stake in AI Truck-Driving Startup," Bloomberg, Lulu Yilun Chen and Gillian Tan, June 2021.

Autonomous trucking deals and exits ($M)



Source: PitchBook | **Geography:** Global
*As of June 25, 2021

Autonomous trucking deals and exits (#)



Source: PitchBook | **Geography:** Global
*As of June 25, 2021

Top investors in autonomous trucking by investment count

Investor	Investments*
Plug and Play Tech Center	8
Y Combinator	8
US Department of Defense	5
WeiVC	5
Canada Pension Plan Investment Board	4
DCVC	4
Full Truck Alliance	4
GSR Ventures	4
Maven Ventures	4
Mubadala Capital-Ventures	4
Sequoia Capital	4
8VC	3
AV8 Ventures	3
China Growth Capital	3
Dynamo Ventures	3
EQT Ventures	3
Ericsson Ventures	3
Fontinalis Partners	3
Founder H Fund	3
G7 Ventures	3
GLP	3
New Enterprise Associates	3
NIO Capital	3
NordicNinja VC	3
Norrsken VC	3
Perry Creek Capital	3
SAIC Capital	3
Sequoia Capital China	3
SV Angel	3
Tiger Global Management	3
Trucks Venture Capital	3

Source: PitchBook | **Geography:** Global
*As of June 25, 2021

Trucking automation has received significant capital investment, with several startups listing publicly and obtaining valuations on par with robotaxi companies. In the first half of 2021, investors poured $5.6 billion into autonomous trucking companies such as TuSimple, Plus, and Embark, which already eclipses the $4.2 billion invested in 2020 and marks a record for the autonomous trucking space. Major deals in Q2 2021 include Waymo's $2.5 billion late-stage round, TuSimple's $1.4 billion IPO, Embark Trucks' $414.0 million special purpose acquisition company (SPAC) and accompanying $200.0 million PIPE deal; and Plus's $345.0 million SPAC, which included a $150.0 million PIPE deal. Investment has been concentrated in late-stage leaders, with six late-stage deals completed in H1 2021 (versus two in all of 2020), compared with three early-stage deals (versus 12 in 2020).

The autonomous trucking space has attracted diverse investors. Strategic transportation investors include Hyundai (KRX: 005380), Kia (KRX: 000270), Navistar, BMW i Ventures, NIO Capital, and Magna International (TSE: MG). Logistics companies Amazon, Prologis (NYSE: PLD), and UPS (NYSE: UPS) have each made bets in the space, including Amazon purchasing the option to buy 20.0% of Plus. VC firms with a focus on the industry include Sequoia, DCVC, Dynamo Ventures, FM Capital, Fontinalis Partners, NordicNinja VC, 10X Capital, and Trucks Venture Capital. Finally, large asset managers active in the industry include Canada Pension Plan Investment Board, Tiger Global Management, Fidelity Management, and T. Rowe Price (NASDAQ: TROW).

Exit activity has heated up for autonomous trucking companies—partially driven by TuSimple's successful IPO in April 2021, wherein it raised over $1 billion at an $8.5 billion post-money valuation. As we predicted in our 2021 Emerging Technology Outlook, SPAC activity has also been robust. Plus, Embark, and Aurora each announced plans to merge with SPACs, while Waymo has been linked to a potential market listing. Relative to traditional IPOs, SPAC listings tend to receive less scrutiny and have become popular in the mobility space, wherein startups are characterized by money-losing, cash-burning, highly capital-intensive business models—many of which are pre-revenue.

In our Q2 2020 Mobility Tech report, we observed that the widening gap between autonomous trucking and robotaxi valuations appeared to be at odds with the near-term opportunity in automating logistics. One year later, this gap appears to be narrowing. Between July 2020 and July 2021, the total value of the four largest robotaxi companies increased only 12.1%—from $64.3 billion to $72.1 billion. At the same time, the total value of the four largest autonomous trucking companies increased 438.1%—from $5.8 billion to $31.2 billion. Just one year ago, the highest-valued autonomous driving companies—such as Waymo and Cruise, each valued at north of $30 billion—were primarily focused on robotaxis. As of mid-July 2021, Waymo is investing more into its autonomous trucking program, TuSimple is the first autonomous driving company to go public, and Aurora is now the third-most-valuable autonomous driving company after Waymo and Cruise. The latest valuations for Waymo and Argo AI have not been disclosed, so these numbers could change.

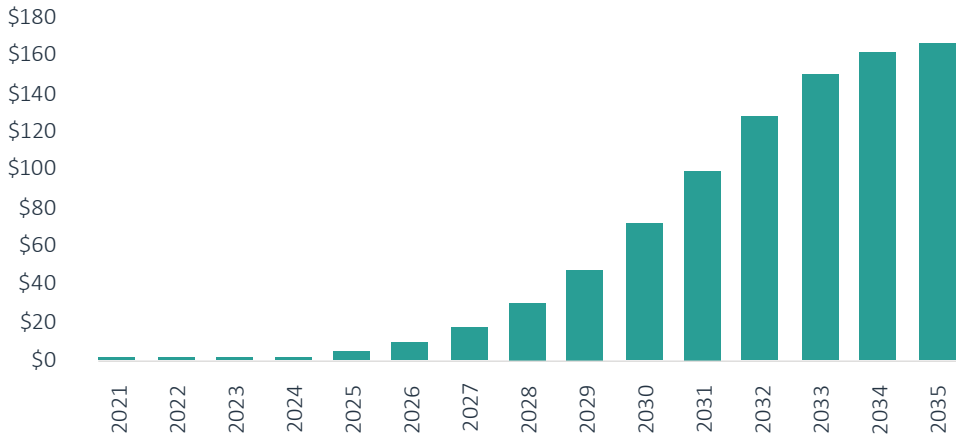
Market valuations for select autonomous trucking and robotaxi companies

Focus	Company	July 2020 ($B)	July 2021 ($B)*	Change
Robotaxis	Waymo	$30.8	$30.8	N/A
	Cruise	$19.0	$30.0	57.9%
	Argo AI	$7.3	$7.3	N/A
	Uber ATG	$7.3	$4.0	-44.8%
	Robotaxis total	**$64.3**	**$72.1**	**12.1%**
Autonomous trucking	Aurora	$3.1	$13.0	319.4%
	TuSimple	$1.2	$9.8	712.5%
	Plus	$1.0	$3.3	230.0%
	Embark	$0.5	$5.2	932.0%
	Autonomous trucking total	**$5.8**	**$31.2**	**438.1%**

Source: PitchBook | **Geography:** Global
Note: Latest valuations for Waymo and Argo AI are undisclosed.
*As of July 16, 2021

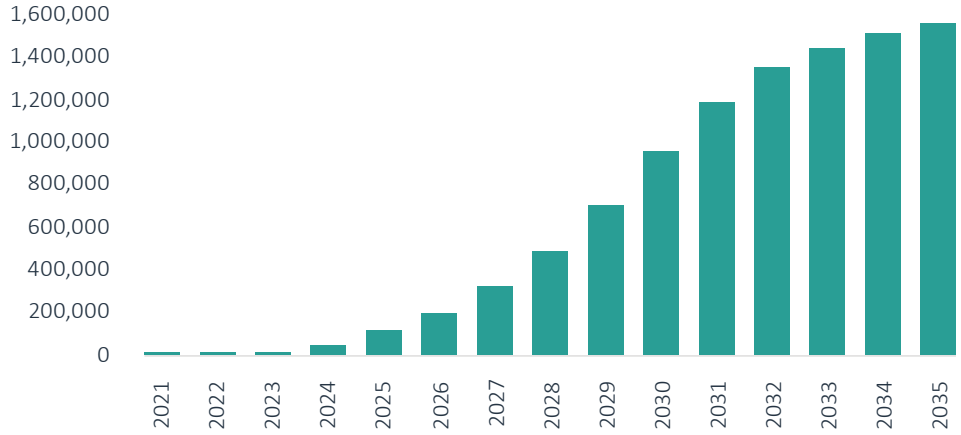
Market projections

Autonomous trucking industry global revenue ($B)



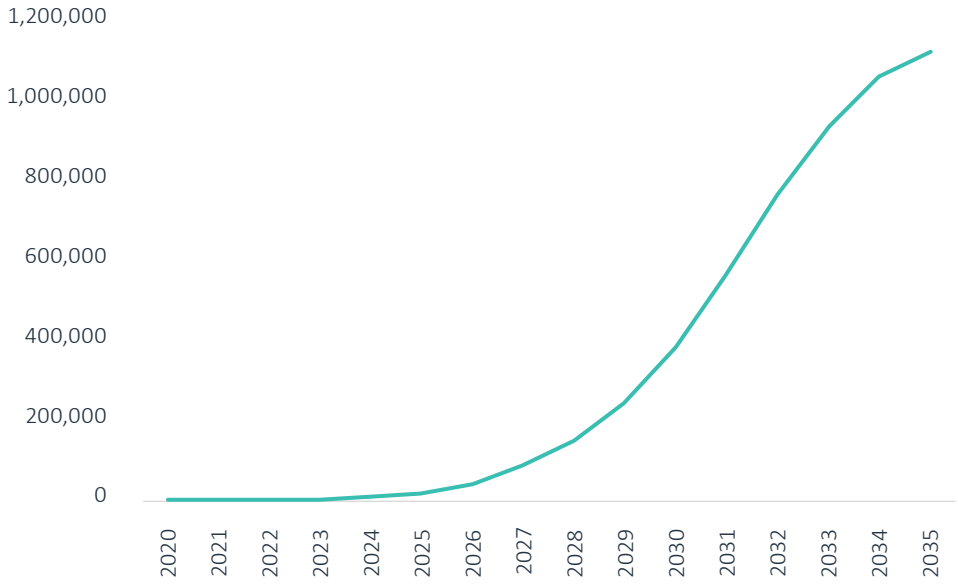
Source: PitchBook Emerging Tech estimates | **Geography:** Global

New Level 4-enabled truck unit sales



Source: PitchBook Emerging Tech estimates | **Geography:** Global

Autonomous miles driven (millions)



Source: PitchBook Emerging Tech estimates | **Geography:** Global

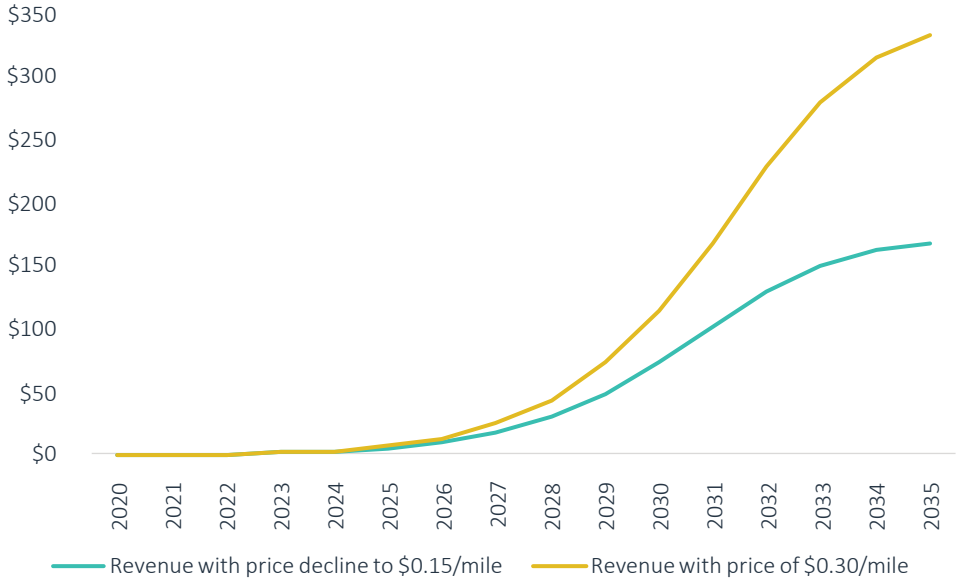
We forecast the global market for autonomous trucking will grow from $528.0 million in 2023 to $166.8 billion in 2035. Initially, we expect autonomous driving technology to augment human drivers, but by mid-decade we anticipate Level-4 driverless trucks will begin to take over long-haul transport. Over the long term, we anticipate improvements in the technology will enable autonomous trucks to take over the entire trip.

We project new Level 4-enabled truck unit sales to rise from 16,500 in 2023 to 1.6 million in 2035. At this point, we believe autonomous trucks will comprise the majority of global truck sales. Over the long term, we expect continued adoption of autonomous trucks will drive additional sales as the market for shipping expands.

Initially, we forecast that trucks will average approximately 100,000 autonomous miles annually. As the technology improves, we anticipate utilization will grow to 150,000 autonomous miles annually, thus further expanding the market.

Our model shows that although hardware costs will remain high over the near term, the majority of long-term autonomous trucking revenue will come from software. For this reason, leading autonomous trucking technology providers must develop expertise in functions such as teleoperation, mapping, and data processing to maintain their lead.

Autonomous trucking industry global revenue ($B) by price per mile

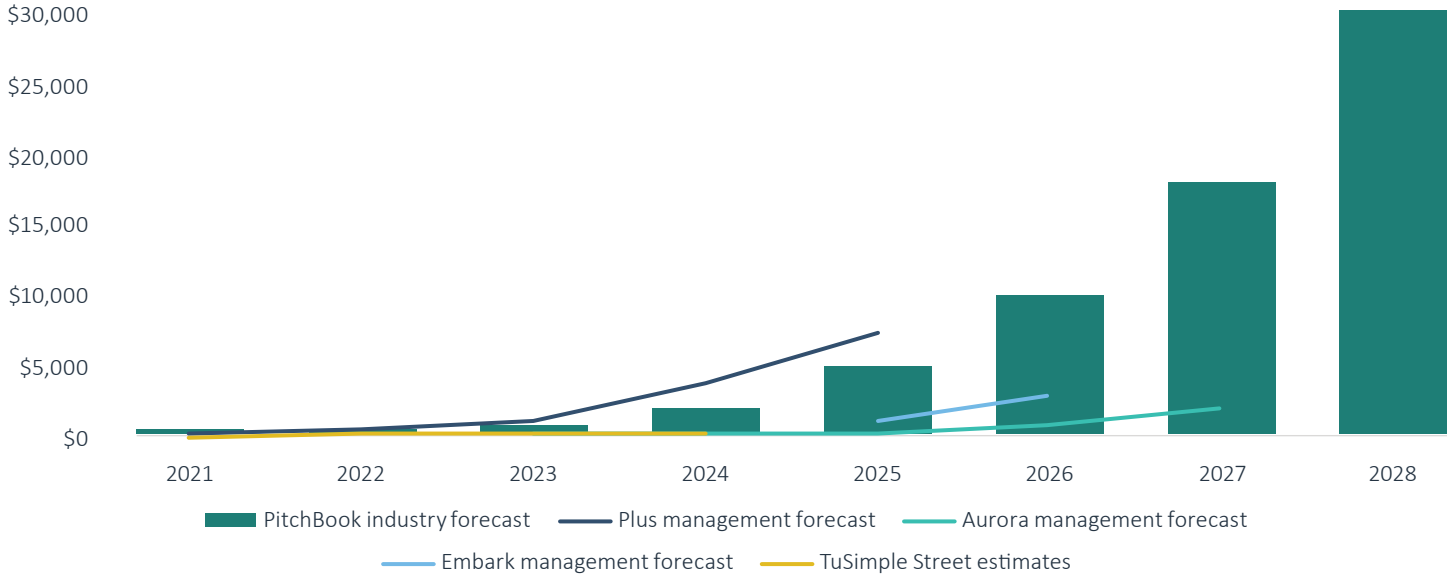


Source: PitchBook Emerging Tech estimates | **Geography:** Global

Aurora, Embark, and Plus forecast revenue per mile of $0.31 to $0.66. In our view, prices higher than $0.59 per mile are unlikely to be tenable to fleet customers, as that would offset the cost savings from replacing drivers. Instead, we expect revenue per autonomous mile to start at approximately $0.30 per mile. According to our model, if the autonomous trucking industry can maintain prices at approximately $0.30 per mile, the industry could achieve $331.5 billion in revenue in 2035. However, we view this scenario as unlikely to occur.

We expect autonomous driving companies will struggle to maintain pricing and expect revenue per autonomous mile to decline to $0.15 over the long term as competition enters the market and sensor costs continue to decline. This pricing pressure will reduce the total market opportunity for autonomous trucks and compress margins for autonomous technology providers.

Autonomous trucking global revenue ($M) with select company estimates

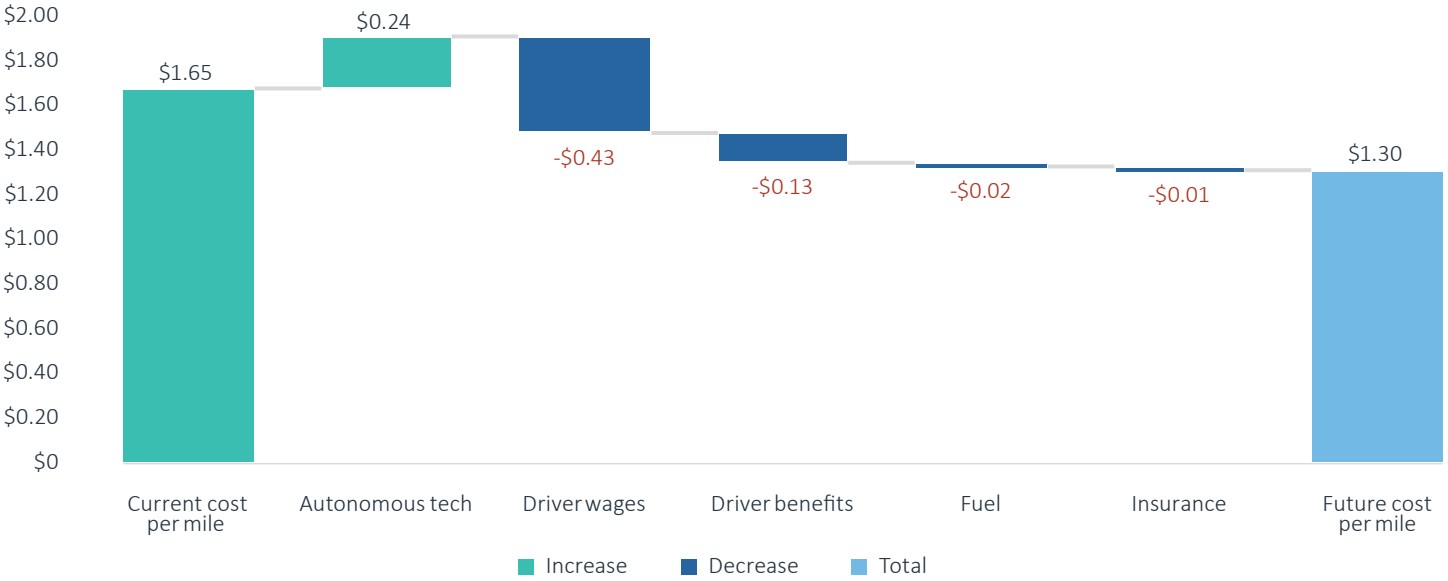


Source: PitchBook Emerging Tech estimates | **Geography:** Global
Note: Plus, Embark, and Aurora revenue estimates pulled from management projections. TuSimple expected revenue pulled from Wall Street estimates.

Expectations for revenue generated by autonomous trucking companies vary greatly. In particular, Aurora's projections for the adoption of its technology are far below those of competitors Embark and Plus. In 2025, Aurora projects it will generate trucking revenue of just $113 million, while Plus and Embark project 2025 revenues of $7.3 billion and $2.8 billion, respectively. In our view, Aurora's forecasts are more reasonable than its peers, and in line with the likely growth trajectory of the autonomous trucking industry.

Unit economics analysis

Current and future trucking costs per mile



Source: PitchBook Emerging Tech estimates, ATRI data used with permission from the American Transportation Research Institution | **Geography:** Global

Our unit economics analysis shows that by enabling hub-to-hub transportation, autonomous driving technology could reduce the cost of trucking from $1.65 per mile today to $1.30 by mid-decade. Over the long term, electric powertrains and further advancements in autonomous driving that enable complete autonomy could shrink the per-mile cost below $1.00. The potential benefits from autonomous driving include increased capacity to ease supply chain constraints, increased driver productivity to offset labor shortages, reduced overall transportation costs from lower labor and fuel expenses, and fewer collisions.

Autonomous driving cost

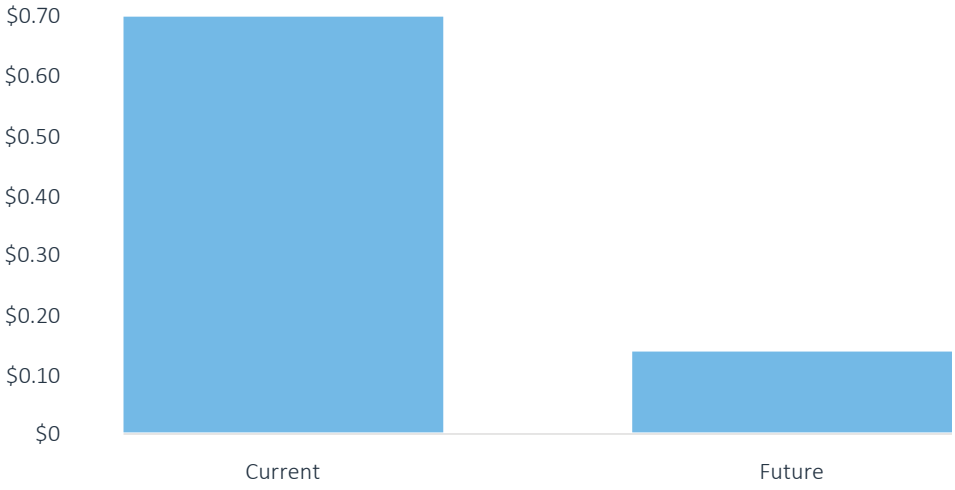
Autonomous driving cost breakdown per vehicle	
Upfront hardware cost	$10,000
Lifespan of truck (years)	10.0
Amortized annual hardware cost	$1,000
Annual software cost	$10,000
Total annual cost	**$11,000**
Autonomous miles driven	100,000
Cost per mile	$0.11
Price per mile	$0.24
Gross margin	**55.0%**

Source: PitchBook

Retrofitting and integrating autonomous driving technology will likely involve sizable upfront capital expenses for hardware and ongoing costs for software and maintenance. We estimate autonomous hardware currently costs over $100,000 per vehicle due to expensive lidar systems, onboard computers, and custom installation and integration. However, this could shrink to $10,000 per vehicle by the mid-2020s, driven by lower-cost solid-state lidar, standardized integration, and high-volume manufacturing. We expect autonomous driving software to cost $10,000 annually for ongoing annotation, teleoperation, and data processing services. Amortized over a 10-year lifespan, autonomous driving technology costs could land in the range of $11,000 per year, or—assuming 100,000 miles traveled per year—$0.11 per mile. This compares to our estimate that autonomous trucks could generate revenue of roughly $0.24 per mile in 2025, which is a conservative forecast relative to Embark's forecast of $0.31 to $0.38, Aurora's forecast of $0.57, and Plus' forecast of $0.53 to $0.66.

Reducing labor costs

Per-mile truck driver wages and benefits

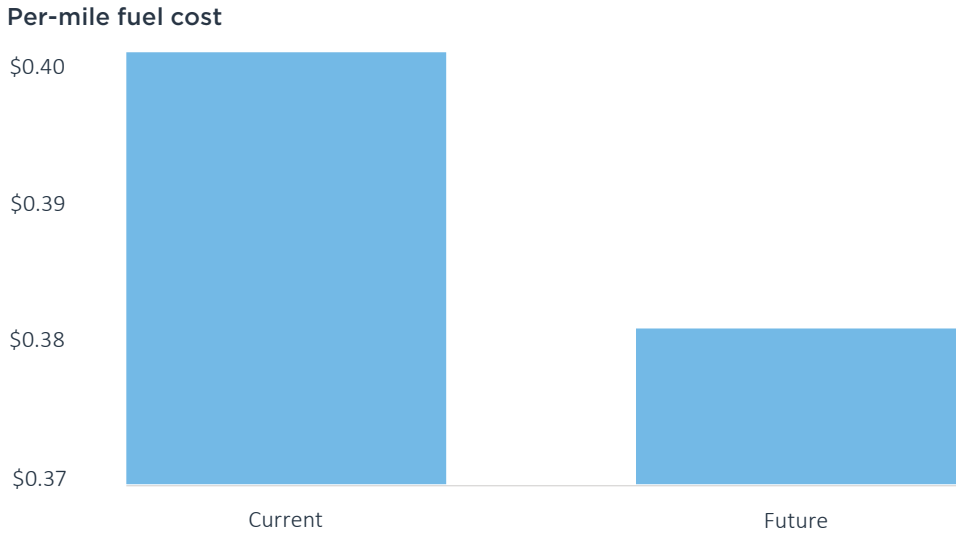


Source: PitchBook Emerging Tech estimates | **Geography:** Global

The reduction in truck drivers carrying out long-haul trips should result in a significant decline in per-mile driver costs. For this analysis, we make two assumptions. First, we assume drivers will still be needed to carry out trips between distribution centers in urban areas and transfer hubs. Second, we assume the average distance between urban centers and future transfer hubs will be approximately 100 miles. According to the American Truck Associations, the average haul was 527 miles in 2017.[3] This implies that drivers will be needed for approximately 19.0% of current mileage, which reduces the driver cost by 81.0%. As a result, we expect per-mile driver wages and benefit costs to decline from 69.3 cents per mile to 13.3 cents per mile.

3: "As Average Length of Haul Falls and E-commerce Grows, How Is the Truck Population Changing," Trucks Parts and Service, Lucas Deal, July 28, 2020, updated January 28, 2021.

Reducing fuel costs



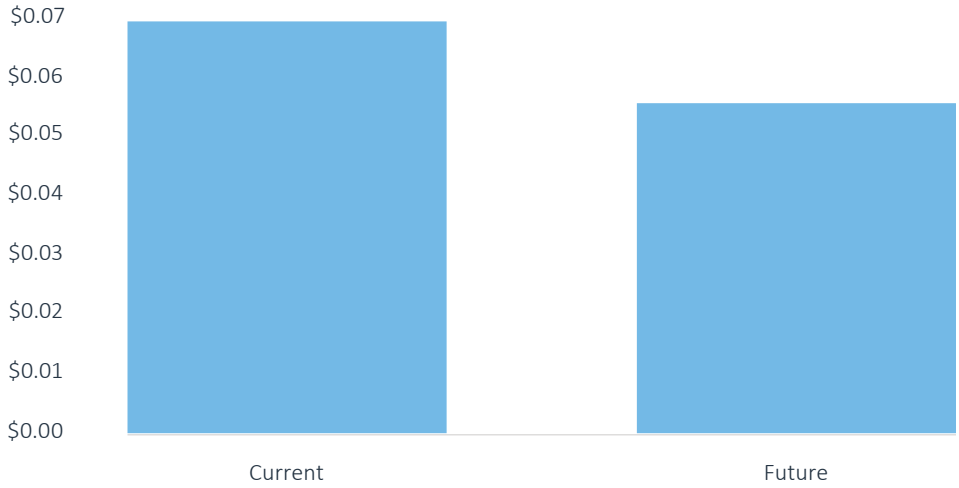
Source: PitchBook Emerging Tech estimates | **Geography:** Global

Autonomous trucks may also reduce fuel costs by platooning, or driving in formation closely behind a leader to reduce air resistance. A University of Leeds study estimated that platoon leaders and followers could reduce fuel consumption by 5% and 10%, respectively.[4] Startups such as Locomation and Peloton are currently developing truck platooning technology, and OEMs including Volvo and Scania are running trials. However, the business case for platooning may be limited. Notably, Daimler has pulled back from platooning, citing limited benefits on European roads. Additionally, platooning requires synced departure times, which means any logistical delays can have cascading effects, thereby eliminating the benefits of modest fuel gains. We conservatively model a 5.0% reduction in fuel costs resulting from improved driving efficiency and platooning, which lowers fuel costs from 39.6 cents per mile to 37.6 cents per mile. Over the long term, battery and hydrogen electric are more likely than platooning to improve energy efficiency.

4: "A Business Model and Cost Analysis of Automated Platoon Vehicles Assisted by the Internet of Things," Journal of Automobile Engineering, University of Leeds, Junyan Chen, et al., August 27, 2020.

Safety and insurance costs

Per-mile insurance cost



Source: PitchBook Emerging Tech estimates | **Geography:** Global

Autonomous trucking has the potential to reduce human-caused collisions. As trucks are 20x to 30x heavier than passenger vehicles, trucking accidents are often fatal. In 2019, 4,119 people in the US died in collisions involving trucks, and 82% of fatalities were passenger vehicle occupants, pedestrians, bicyclists, or motorcyclists.[5]

As the technology develops, autonomous trucks will likely reduce fleet operators' insurance costs, which have been on a steady increase over the past few years. Insurance costs are rising partly due to an increase in liability suits. According to the American Transportation Research Institute (ATRI), insurance premiums reached 8.4 cents per mile in 2018, up from 5.9 cents per mile in 2010.[6] Although insurance costs declined to 6.8 cents per mile in 2019, this was driven by trucking fleets assuming higher risk levels through higher deductibles, self-insurance, and reduced liability coverage, and the ATRI expects insurance costs will continue to increase.[7] We expect adoption of autonomous driving technology—ranging from automatic emergency braking and collision avoidance systems to full self-driving—to reduce insurance costs by 20.0% to 5.4 cents per mile.

5: "Large Trucks," IIHS, April 2021.
6: "Experts: Fleets Should Expect Even Higher Insurance Costs," Transport Topics, February 26, 2020.
7: "An Analysis of the Operational Costs of Trucking: 2020 Update," American Transportation Research Institute, Nathan Williams and Dan Murray, November 2020.

Autonomous trucking growth drivers

Driver shortage most severe in long-haul trucking: In 2018, the ATA forecast that the trucking industry needs 60,800 more drivers in the US to meet demand.[8] The COVID-19 pandemic and new regulations requiring drug testing and restricting hours worked exacerbated this shortage.[9] The shortage will likely worsen over the coming years given the higher average age US truck drivers—48 years old—relative to other blue-collar occupations.[10]

Long-haul, or long-distance trucking, faces the most severe shortage with turnover rates near 90%.[11] Long-haul trucking is a stressful occupation, with significant deadline pressure, long hours, and extended time away from home. Drivers are also generally not compensated for traffic-, weather-, or loading-related delays. Compared to other areas of autonomous driving, long-haul trucking could see relatively easier adoption given it involves long, straight highways with little traffic, obstacles, or variables.

Workforce implications are overblown: We believe fears that autonomous trucks will cause massive workforce disruption are overblown. As our market forecast indicates, the number of autonomous trucks deployed will not eclipse the existing driver shortage for some time. Even as these vehicles deploy, they will initially focus on long-haul trucking, which has the most pronounced labor shortage.

Rather, we believe autonomy will more likely help augment the trucker workforce by both making trucks safer and automating the less desirable aspects of the job. Initially, long-haul trucks will still require human supervision, but drivers will have time to perform other manual tasks, such as logging hours. Autonomous driving may also shift the human workforce toward intracity and last-mile transport, as well as necessitate teleoperation jobs to remotely support long-haul trips.

Technology, infrastructure, and regulatory progress still needed: Autonomous trucks will face difficulties in commercializing at scale until clear regulatory guidelines are established for testing, deployment, driver licensing, and driver hours of service. For example, an expansion in allowable miles driven will be key to improving the utilization of autonomous trucks and speeding up shipments. The ATRI has urged policymakers to avoid implementing policies delaying autonomous truck testing and deployment.[12] Various states have developed disparate, incongruent regulatory frameworks, which presents challenges for interstate routing. Some states require trucks to be under constant control by both drivers and engineers—a barrier to scaling of commercial services. Until clear frameworks are set at the federal level, regulation could be a constraint delaying adoption of autonomous vehicle technology. The autonomous trucking industry must proactively work with agencies such as the Department of Transportation (DOT), Federal Motor Carrier Safety Administration (FMCSA), and the National Highway Traffic Safety Administration (NHTSA) to help inform and influence future guidelines.

8: "ATA Issues Updated Driver Shortage Report, Forecast," Bulk Transporter, Informa Commercial Vehicle Staff, July 13, 2019.
9: "Is There Really A Truck Driver Shortage?" NPR Planet Money, Greg Rosalsky, May 25, 2021.
10: "Driving Automation Systems in Long-Haul Trucking and Bus Transit: Preliminary Analysis of Potential Workforce Impacts," US Department of Transportation, January 2021.
11: "US Truckload Driver Turnover Flattens as Wages, Demand Rise: ATA," Journal of Commerce Online, William B. Cassidy, March 30, 2021.
12: "Patchwork of Self-Driving Laws Limiting Autonomous Truck Innovations," FleetOwner, Josh Fisher, February 3, 2020.

Although autonomous trucking is further along in development than robotaxis, additional technological development will be required before mass commercialization. For example, even the leading autonomous cars from Waymo struggle with merging onto highways. Semitrucks, which are often more than 20 meters long, present another layer of complexity. Dealing with unpredictable traffic and inclement weather conditions will also pose a hurdle. Integrating autonomous technology with truck chassis will be important for redundancy, and this will necessitate rethinking the entire architecture of future truck chassis. In this regard, we see Torc Robotics (acquired by Daimler) as a leader.

Autonomous truck fleets will also require a network of dedicated infrastructure. This may include transfer hubs for loading and unloading near highways, service infrastructure to deal with unexpected on-road repair and maintenance issues, and teleoperations centers for remote assistance.

Advances in solid-state lidar will drive technological advancement: We believe the lidar industry is shifting away from traditional spinning applications and toward solid-state applications with fewer moving parts. While spinning lidar has set the industry standard for performance, it can be bulky and raises concerns about longevity as automobiles are constantly subject to fluctuations in temperature, vibration, and weather conditions. Solid-state applications tend to be smaller and are more easily integrated onto vehicle bodywork. Additionally, fewer moving parts could result in reduced costs associated with repair, replacement, and maintenance for fleet operators. Solid-state lidar companies with exposure to autonomous trucks include Ouster (announced partnership with Plus), Luminar (Daimler), Aeva (TuSimple), and AEye (TuSimple). Aurora is also a leader in the space, with its acquisitions of frequency-modulated continuous-wave (FMCW) lidar startups Blackmore and OURS.

Large providers best positioned to consolidate industry: We expect autonomous technology to spur a wave of consolidation transforming the trucking industry in favor of large companies. Companies such as Amazon, Walmart, XPO, and J.B. Hunt will likely be the largest initial buyers of autonomous trucking technology. As these companies build out their autonomous fleets, they will enable faster trips than competitors and drive down industrywide freight prices. Further, larger companies will be better positioned to invest in supporting networks such as transfer hubs, thus enabling autonomous transport, repair and maintenance centers, teleoperations centers, cellular communications, and data processing. Both factors will pressure smaller carriers without the ability to invest in autonomous technology. This trend may also make it harder for smaller providers to find and retain workers or drivers.