www.pwc.com

Industrial Mobility

How autonomous vehicles can change manufacturing

February 2018

pwc

MANUFACTURING Institute

Contents

I Introduction and key findings **3**

II Industrial mobility: Inside the factory walls **7**

III Industrial mobility: The extended supply chain **12**

IV Where do you fit in? An industrial mobility self-assessment **26**

I Introduction and key findings

I Introduction and key findings

The popular fascination with self-driving passenger cars has opened a new era of how we envision moving people. Meanwhile, a parallel lane has also opened: automating how we move things. While we have yet to marvel at convoys of driverless and digitally connected eighteen-wheelers, or even set cargo-hoisting drones aflight, they seem nearly visible on the horizon.

With about 16 billion tons of goods and commodities shipped annually in the US, a wide group of players—large industrials, start-ups, state and municipal governments to name a few—are rushing to develop and deploy automated and, ultimately, autonomous transport of goods, including raw materials, parts, and finished product.[1]

We call this *industrial mobility*, and it covers a wide swath of transportation modes—from mobile and autonomous robots on factory floors, to autonomous trucking, drones, rail and marine transport in public roads, air space, tracks and waterways. It's important to point out that, while this report considers industrial mobility deployment both in private facilities and in the public domain, we do believe that as technology is embraced, the line dividing private and public industrial mobility deployment is already blurring and will continue to do so.

To get a sharper view of where we are and where we're going in industrial mobility, PwC and the Manufacturing Institute (MI) carried out a survey of 128 large and mid-sized US manufacturers and transportation companies.

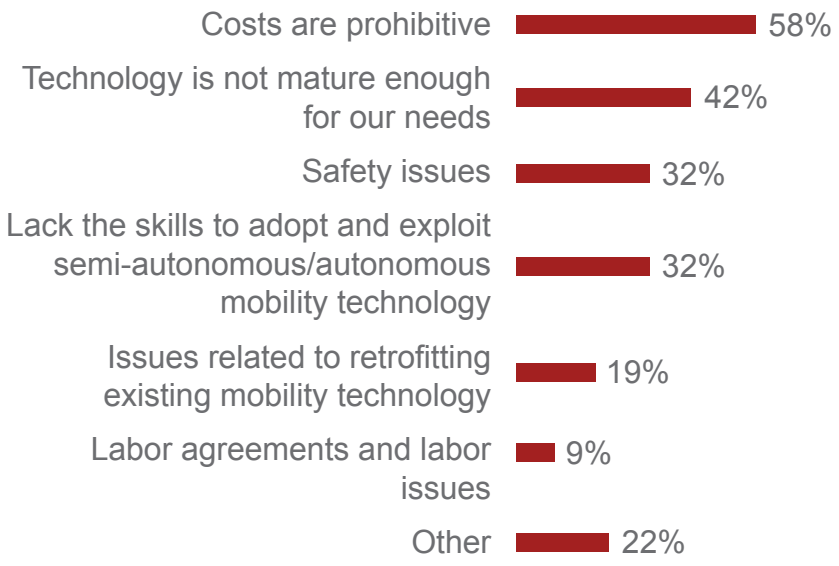
What we found is that, while automated and autonomous mobility technologies are being developed and piloted—and, in some cases, already commercially available—manufacturers seem very much at the early stages of the adoption curve. Most manufacturers seem poised in a "wait-and-see" mode, but do expect to adopt autonomous mobility solutions once they become affordable, are proven to be reliable and safe, and demonstrate returns on investment.

Key findings of the PwC/MI Industrial Mobility Survey include:

- Just 9% of manufacturers have adopted some type of semi-autonomous or autonomous mobility within their operations, with another 11% expecting to do so in the next three years.
- The top trigger for manufacturers to adopt industrial mobility technologies (i.e., from mobile robots to autonomous trucks) is cost advantage (86%) followed by customer/supply expectations (47%) and increased safety (38%).
- Nearly 60% of manufacturers cite cost as one of the top barriers of adoption of semi-autonomous and autonomous vehicles within their plants, followed by immature technology (42%), safety issues (32%) and lack of talent (32%).
- Roughly 90% of US manufacturers believe that fully autonomous trucks could, when mainstreamed, save up to 25% of their total trucking costs.
- 65% of US manufacturers believe that self-driving trucks will be mainstreamed within the next 10 years.

On industrial mobility, manufacturers are still in a wait-and-see mode...

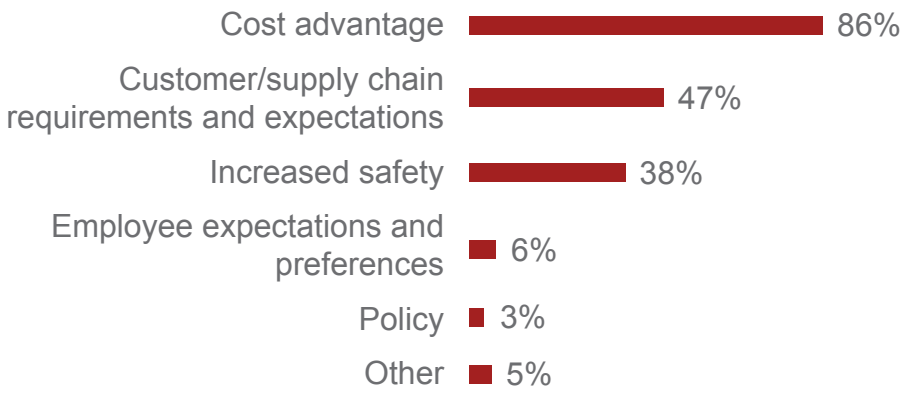
Q. What are the barriers to entry or adoption of semi-autonomous/ autonomous vehicles within the plant? (Check all that apply.)



Respondent number: 90
Source: PwC/Manufacturing Institute Industrial Mobility Survey

...Yet also recognize potential cost advantage in adopting industrial mobility

Q. What are the most likely factors that will prompt your company to adopt advanced industrial mobility technologies? (Note: Respondent may choose more than one.)



Respondent number: 93
Source: PwC/Manufacturing Institute Industrial Mobility Survey

In addition to the survey, we analyzed recent US investment activity in industrial mobility technology start-ups. We also modeled scenarios of how mainstreaming of autonomous trucking could impact manufacturers' transportation costs.

Key findings from PwC analyses include:

- **US investment in non-auto mobility start-ups surges.** A PwC analysis of US investments in private mobility companies over the last five years showed that a total of $6.8 billion has been invested in mobility start-ups in the 2012-2017 period. Of this amount, we found that $2.6 billion was invested in companies developing technology supporting autonomous passenger vehicles development (self-driving autos) and $4.2 billion in companies focused on technology for broad-use, non-auto autonomous mobility (mobile robots, unmanned aerial vehicles, autonomous forklifts, freight trains, marine vessels, etc.). To put this in perspective, a similar PwC analysis (based on CB Insights data) showed that US investments in 3D-printing start-ups totaled $750 million in the 2012-2017 period.
- **Mainstreaming of self-driving long-haul trucks could cut manufacturers' transport costs by 30% through 2040.** A PwC analysis estimates autonomous, long-haul trucking could save manufacturers nearly 30% in total transportation costs through 2040, assuming aggressive adoption of autonomous trucking.

Many incremental steps on road to autonomy. As elements of automation begin to roll out in all modes of transportation, it is likely that adopters will experience incremental adoption on the road to full autonomy. Also, it is likely that certain modes of autonomous transport, especially those that are used on privately-owned territory (e.g., mine pits, or inspection of assets in remote areas, such as the ocean or unpopulated areas) will advance more quickly than others (e.g., delivery or inspection drones in urban areas) along the adoption curve. As autonomous vehicles (both passenger and freight) are piloted, advances in reliability and safety will surely dictate the pace, breadth and locales of adoption.

A caution sign for drivers/operators? The question of whether workforces are prepared to embrace autonomous vehicles is another matter. As autonomous systems first assist, then replace, drivers and operators, manufacturers (as well as other industries) will need to prepare for a momentous talent shift and, in some cases, displacement. Demand for humans at the wheel in a world of autonomous transport modes will more likely usher in a new generation of logistics technicians—not drivers/operators—to oversee the software and algorithms that may be in the proverbial driver's seats of the future.

II Industrial mobility: Inside the factory walls

II Industrial mobility: Inside the factory walls

Moving from mechanized to autonomous. Automating the movement of materials within operations is nothing new for manufacturers. Indeed, automated guided vehicles (AGVs), conveyors, sorters and shuttles have been moving and handling materials, parts and product for decades. Most of this technology, however, has traditionally been limited to prescribed, fixed routes.

The difference now is that robotics, sensor technology, 3D camera systems, software and artificial intelligence are opening up a new age of autonomous materials handling equipment with minds of their own—machines capable of seeing their environments and, increasingly, *learning* to identify what they're seeing. Industrial robotics, too, have moved from fixed cages to collaborative (working side-by-side with humans) to mobile, "free-range" robots.

The difference now is that robotics, sensor technology, 3D camera systems, software and artificial intelligence are opening up a new age of autonomous materials handling equipment with minds of their own.

Increasingly, semi-autonomous and even fully autonomous vehicles within manufacturing operations (and, in the field, such as in mining) are gaining independence. These can include an ever-growing list: free-range AGVs, mobile robots, autonomous forklifts and cranes—and even low-payload drones. The global automated material equipment handling market is expected to reach $48.3 billion by 2023 from $28.3 billion in 2016 for a 7.8% CAGR between 2017 and 2023.[2] Materials handling robots, in particular, are making aggressive moves, most notably in warehouses and inventory management. Amazon, which has ramped up its warehouse automation, is a prime example. Just consider that, since 2014, while Amazon has hired 50,000 new human workers at its warehouse facilities, it has also added 30,000 robots to work with them.[3]

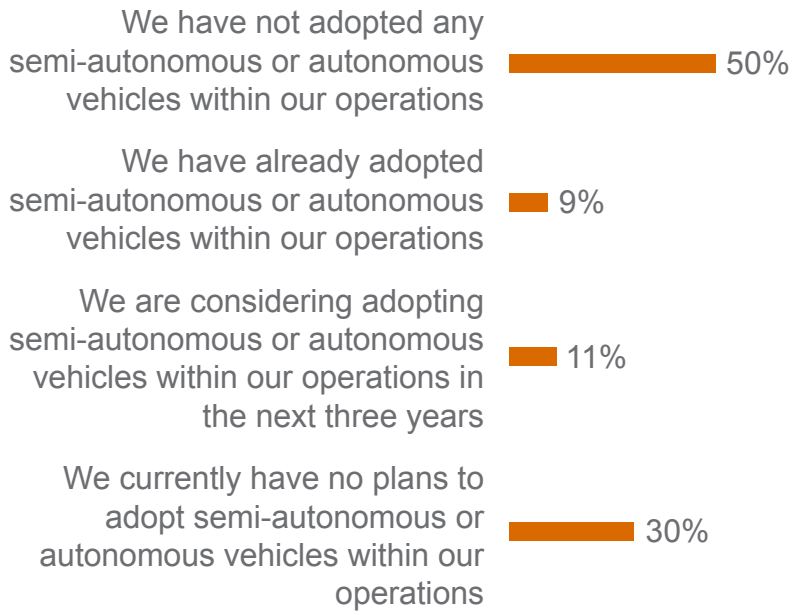
Interestingly, as growth in the automated materials handling equipment market is expected to grow, so too is the hiring of humans working in the industry. According to the US Bureau of Labor Statistics, jobs growth in transportation and materials handling is forecasted to grow by 4.8% over the 2014-2024 decade (latest available data) adding 466,000 to the 9.7 million that existed in 2014 (compared to a total growth projection of 6.5% across all occupations over that period).[4] However, these (human) jobs may well look different than the ones existing today, as robot populations grow on warehouse and factory floors.

Interestingly, as growth in the automated materials handling equipment market is expected to grow, so too is the hiring of humans working in the industry.

Slow adoption…but achieving traction. Still, only one in ten manufacturers currently uses semi-autonomous or autonomous vehicles within their operations, our survey finds, yet an additional 11% plan to do so in the next three years. While a 20% adoption rate in three years may appear paltry, that figure nevertheless suggests manufacturers are on a path leading toward the mainstreaming—considered by some to be attained at 30% adoption of a given technology—of automated/autonomous vehicle technology. Interestingly, of those companies adopting semi-autonomous vehicles within their operations, about four in five have yet to experience cost savings in materials handling as a result of doing so, and the remaining 20% experienced costs savings of at least 10%.

Autonomous vehicles deployment within operations gaining traction…

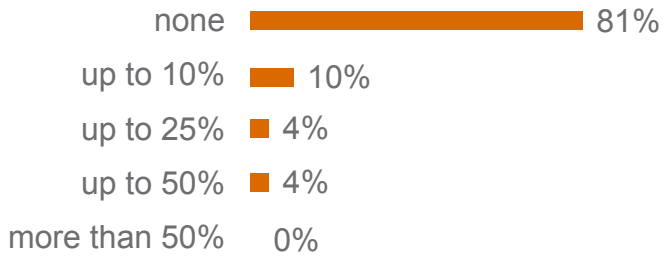
Q. What is your current adoption of semi-autonomous or autonomous vehicles (e.g., traditional automated guided vehicles (AGVs), as well as advanced mobile robotics, automated or autonomous forklifts, unmanned aerial vehicles or drones) within your operations?



Respondent number: 128
Source: PwC/Manufacturing Institute Industrial Mobility Survey

…Yet few manufacturers are already seeing cost-savings and efficiencies

Q. If you have adopted semi-autonomous vehicles within your operations, what degree of annual costs savings (e.g., via efficiencies and labor cost savings in materials handling and products transport) have you experienced as a result?



Respondent number: 48
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Robots are moving in fast….but are we prepared? The deployment of robots is moving swiftly, raising questions about whether it may be, in fact, too swiftly. In 2016, shipments of all types of industrial robots (including mobile robots) totaled 31,404, and are forecast to hit 55,000 in 2020.[5] Meanwhile, the global mobile robot market, according to A to Z Research, forecast to hit $18.7 billion by 2021, up from around $9 billion in 2015.[6] Mobile robots include Fetch's "Pepper" and Karis' "Pro System," start-up IAM Robotics or Fraunhofer's MultiShuttle Move—a "swarm" of small autonomous vehicles for light loads which communicate with one another. Mobile robots are also being deployed for truck-loading duties, including DHL's Parcel Robot and Wynright's truck uploading-and-downloading robot.[7] Or, consider Seegrid's autonomous forklifts, with an 8,000 lb. carrying load.[8] "We have gone from fixed robots in manufacturing plants now to being joined by collaborative robots, out of the cage, and mobile robots. But questions still linger. What standards will govern them? What kind of payloads will they have? Answers to such questions will dictate how much more they can do and how much more widely they will be deployed," said Association for Advancing Automation President Jeff Burnstein in an interview with PwC. "Mobile robot safety standards are another big issue. We could be at a point where the pace of mobile robot technology is outstripping the safety standards that need to govern that technology," Burnstein added.

Flying helpers. Unmanned aerial vehicles (UAVs), or drones (also covered later in this report with regard to their commercial use in public spaces), potentially could be applied in myriad ways within manufacturing operations. First adopters of drones will likely be heavy-asset industries including road manufacturing, utilities, inspecting towers, wind turbines and oil rigs.

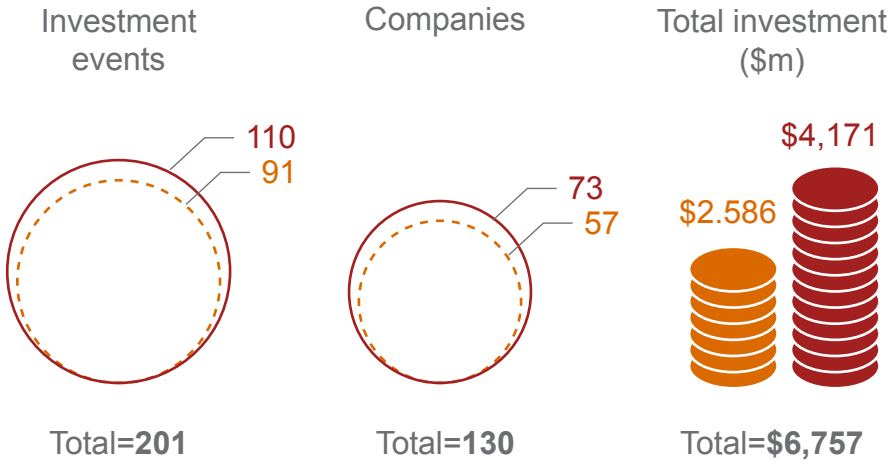
To date, the consumer drone market has captured the headlines—and the sales. Yet, the commercial or "enterprise" drone market is poised to take off, and is forecast to become the fastest-growing drone market sector, with global enterprise drones shipments expected to reach 805,000 by 2021, up from 102,600 in 2016. This compares to global shipments of consumer drones, forecast to reach 10 million in 2017 and rise to 29 million in 2021.[9]

In-plant application of UAVs could potentially help manufacturers with expansive facilities carry out surveillance, such as accessing inventory, yards, docks and movement of assets including the position and movement of forklifts and trucks.

In-plant application of UAVs could potentially help manufacturers with expansive facilities carry out surveillance, such as accessing inventory, yards, docks and movement of assets including the position and movement of forklifts and trucks. Additionally, some drones, especially those capable of higher payloads, could assist in transporting parts, components, tools or materials, for example, within the operations. Because drone use on private property is not regulated by the Federal Aviation Administration (FAA), manufacturers can experiment with drones in novel ways; for example, using drones to pick up or scan items in hard-to-get-places (i.e., in high-level storage).

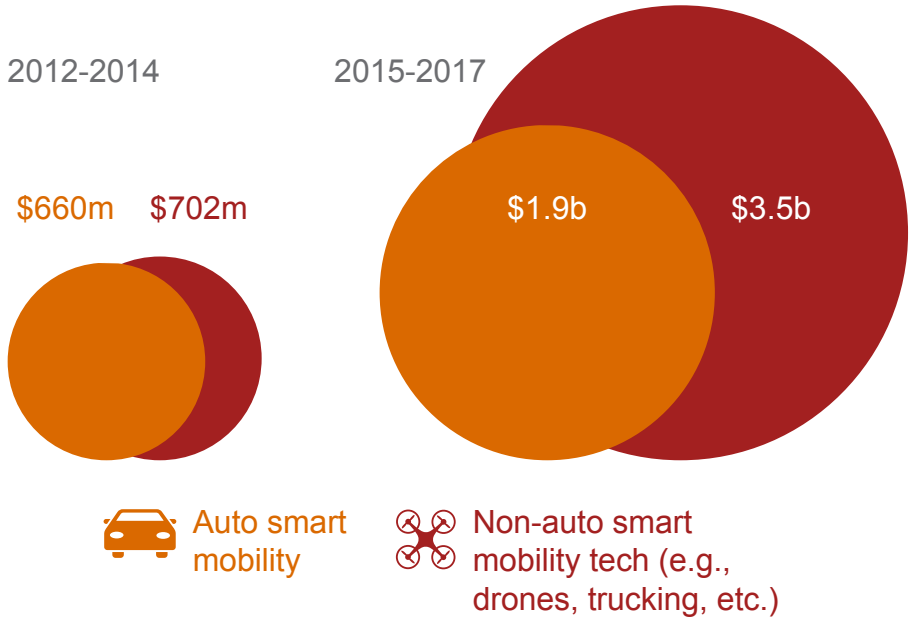
US investment surges in non-auto mobility start-ups. While autonomous vehicles (AVs), or passenger autos, have captured our imaginations—and investment—for some time, there has also been considerable investment activity in non-auto mobility. PwC carried out an analysis of US investments in start-ups receiving at least $5 million that focus on non-auto specific mobility technology—or what we call "broad-use mobility"—which includes automated/autonomous trucking, unmanned aerial vehicles, and advanced maritime mobility. The analysis found that investment in broad-use mobility had actually outpaced that of auto tech in the last five years (see graph), with auto tech receiving $2.6 billion (in 57 companies) in funding compared to $4.2 billion (in 73 companies) invested in broad-use mobility. Interestingly, the lion's share of that investment ($3.5 billion) has occurred in just the last two years.

US investment in private mobility tech start-ups from 8/2012 to 8/2017



Source: PwC analysis, based on CB Insights data

Surge in non-auto tech smart mobility since 2015



Note: Inclusion of companies included in auto and non-auto mobility categories was based on companies' self-descriptions made available to CB Insights

Source: PwC analysis, based on CB Insights data

III Industrial mobility: The extended supply chain

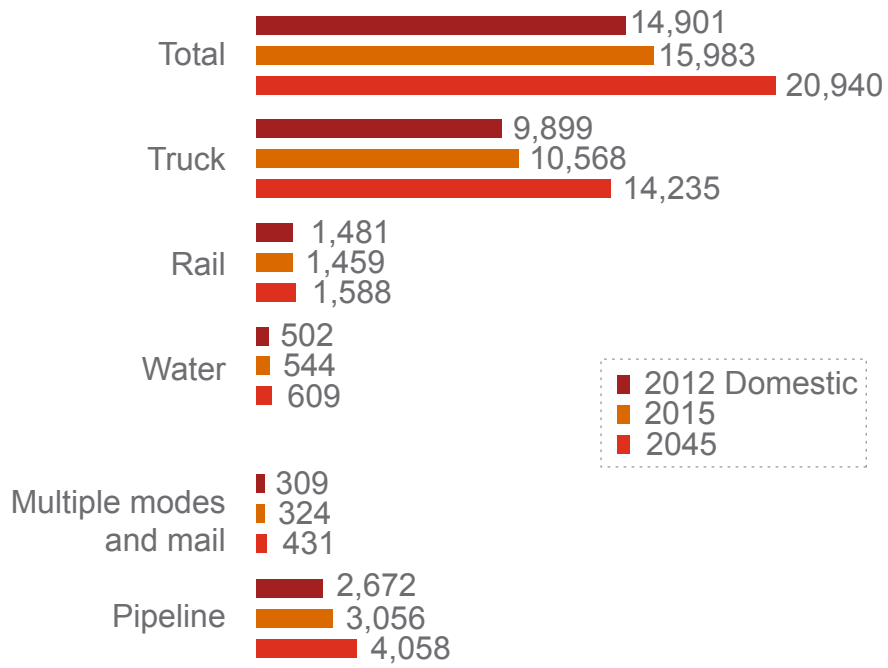
III Industrial mobility: The extended supply chain

The US freight transportation system is massive and sprawling. In 2015, some 16 billion tons of commodities and goods were transported on America's roads, rails, waterways, pipelines and air cargo.[10] The logistics of moving commodities and goods to and from factories and distribution centers has always loomed large for industrial manufacturers since the early days of the industrial revolution. The transcontinental railroad, Panama and Erie Canals, and, later, the interstate highway network opened new paths for the country's economic and industrial development. Today's advent of automated—and, ultimately, autonomous—mobility may very well signal a new era: a fourth transportation revolution of a more efficient, connected, and environmentally friendly transportation system. For many reasons, though, introducing semi-autonomous and autonomous vehicles on public land (and in public space) means hurdling various obstacles to adoption that do not exist within private facilities or privately-owned territory.

A new era of automated trucking? With nearly 70% of all freight (or nearly 10 billion tons) at some point in the US inter-modal supply chain transported by trucks, the future of automated and autonomous trucking may hold important implications for manufacturers going forward.[11] Interestingly, though, most of this movement happens in short-haul routes. In 2015, about half of those goods were moved fewer than 100 miles from origin to destination, and about 7% was moved more than 1,000 miles.[12]

Freight forecast to continue to grow in major transport modes

US Shipments by transportation mode[1]
(millions of tons)



Notes: Numbers may not add to totals due to the fact that only selected major freight transport modes were included.

[1] Data do not include imports and exports that pass through the United States from a foreign origin to a foreign destination by any mode

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, Freight Analysis Framework, Version 4.3.1, 2017.
https://www.bts.gov/bts-publications/freight-facts-and-figures/freight-facts-figures-2017-chapter-2-freight-moved

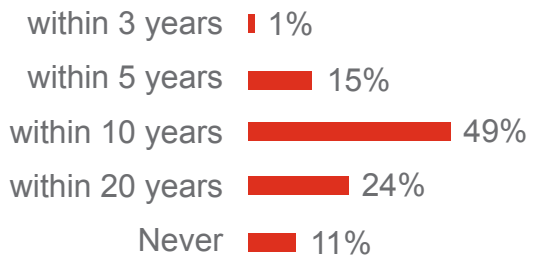
Self-driving trucks: When are they coming? Mainstreamed use of fully autonomous long-haul trucks (attaining an adoption rate of at least 30%) on our highways may be years—or even decades—off. And, mainstreaming of autonomous trucks in last-mile and urban areas may well even take longer, given their more complex environments. According to our survey, 65% of manufacturers believe autonomous trucks will be mainstreamed in the next decade. "I think the technology to support autonomous long-haul trucking technology will approach maturity in the next five to ten years. However, we're still 10 to 20 years off from having fully driverless trucks be a common sight. I think the fear of displacing human workers and the general public's initial safety concerns will keep drivers in the trucks for at least another decade, maybe two, beyond that," Greg Rogers, Policy Analyst at the Eno Center for Transportation, said in an interview with PwC.

The technology to support autonomous long-haul trucking technology will approach maturity in the next five to ten years. However, we're still 10 to 20 years off from having fully driverless trucks be a common sight. I think the fear of displacing human workers and the general public's initial safety concerns will keep drivers in the trucks for at least another decade, maybe two, beyond that.

—Greg Rogers, Policy Analyst at the Eno Center for Transportation

Most manufacturers predict self-driving trucks to be mainstreamed in next decade

Q. When do you believe autonomous trucking (self-driving trucks) for long-haul transport will become mainstreamed as a viable mode of transport in the US?



Respondent number: 100
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Piloting for proof-of-concept of driverless trucks. Pilot programs in several states, including Michigan, California, Florida and Utah, now permit testing automated truck platoons on public roads.[13] Uber's self-driving unit, Otto, retrofits trucks for self-driving, installing motion sensors, cameras, LiDAR (Light Detection and Ranging) and proprietary software to help with driving decisions. Billed as the world's first autonomous truck delivery, Otto was installed on a Volvo semi-truck that traveled 120 miles—from Fort Collins to Colorado Springs, Colorado—to deliver 50,000 cans of Budweiser beer.[14] Caterpillar already has autonomous vehicles toiling away in mining pits, and Rio Tinto is trialing the first fully autonomous heavy-haul long distance rail system to carry iron ore in Australia.[15] Other traditional original equipment manufacturers (OEMs), including Peterbilt, Volvo, and Daimler, are also developing technology around autonomous long-haul trucking. Meanwhile, Tesla, the electric passenger carmaker, announced the development of its "Tesla Semi," an electric-power, semi-autonomous Class 8 semi-truck with a range of 400 miles per charge, which uses autopilot and can be driven with platooning technology.[16] "There are a lot of ways that autonomous systems in trucks can help the logistics industry—improving driver safety, relieving the industry's labor shortage pressures, making the jobs easier, and freeing up drivers to focus on other tasks such as planning routes," Greg Rogers, Policy Analyst at the Eno Center for Transportation, said in an interview with PwC.

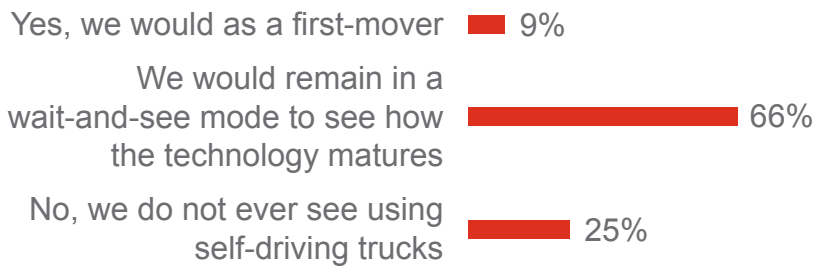
Virtual Drivers Ed? As with all fully autonomous, driverless (Level 5) vehicles, ensuring—and trusting—that machines can acquire the ability to make the right decisions at the right times may well prove to be one of the biggest speed-bumps to mainstreamed adoption on public roads and in public space. However, in a world in which a global open network accommodates the sharing of information amongst vehicles, machines—in theory—could "learn" from one another at a rapid clip, collectively gathering and sharing, for instance, data on hundreds of millions of driving miles for any given week. If such an open machine-to-machine learning network could be realized, we may see autonomous vehicles possessing greater driving knowledge than any person could.

The semi-autonomous truck reality is here. Meanwhile, advancing levels of driver-assisted technologies are becoming common—including active braking assistance, adaptive cruising, or even cameras to check truckers' eyes for sleep-prevention, alarming them if signs of sleepiness are detected. Indeed, our survey found that 5% of US manufacturers are now using semi-autonomous trucks, and about 11% plan to do so in the next three years.

A wait-and-see mood for full autonomy persists. Looking ahead, though, in a world in which self-driving trucks are mainstreamed and proven as safe and viable, two-thirds of US manufacturers would expect themselves to still be in a "wait-and-see" mode, and one in four do not ever expect to use self-driving trucking. Such caution and reluctance, naturally, is understandable.

Most manufacturers in wait-and-see mode with self-driving truck adoption

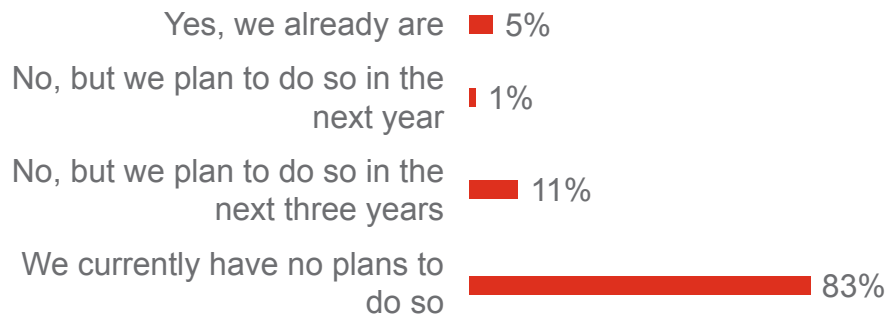
Q. Would your company adopt autonomous trucking (self-driving trucks) for long-haul transport if/when they become mainstreamed as a viable mode of transport in the US?



Respondent number: 102
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Most manufacturers in wait-and-see mode with self-driving truck adoption

Q. Does your company use semi-autonomous trucks for your supply chain and distribution needs (whether or not you own and operate them or your logistics firm does)?



Respondent number: 101
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Platooning: A giant leap into autonomy. A big step toward driverless trucks is already underway with programs piloting "platooning," a technology enabling multiple trucks to travel together in a convoy (tethered by vehicle-to-vehicle communications) but, at the moment, still with operators in the cab. Platooning could offer fuel savings via lowered wind drag on vehicles. For example, Peloton, a platooning technology start-up, estimated that, in its tests, platooning raised the fuel efficiency of a rear truck by 10%.[17] The US Department of Transportation demonstrated a three-truck platoon of partially-automated autonomous trucks in September 2017 in Virginia, showcasing Cooperative Adaptive Cruise Control (CACC), which enables vehicle-to-vehicle (V2V) communication, allowing trucks to drive as a unit.[18] "The big break-through will be in autonomous trucks, with platooning. These systems will march up the autonomy curve—from Level 1 to Level 5—quicker than other modes. It's just a matter of time. With trucking, it will start with safety features. We've seen autonomous tractors for two decades, but there is still a driver in the cab. I think even with Level-5 trucking, we may well still see a driver in the cab," said Tim Harris, CEO of Swift Navigation, a maker of centimeter-accurate GPS systems for autonomous vehicles, in an interview with PwC. "Improving reliability and lowering costs of technology will accelerate the autonomous vehicle market. Sensor suites and cameras are already on this path, but radar, LiDAR, GPS, gyros and compasses in my view, can do more," added Harris.

Peloton, a platooning technology start-up, estimated that, in its tests, platooning raised the fuel efficiency of a rear truck by 10%.

A need for federal autonomous vehicle regulation. Thus far, US states have forged ahead with their own regulations, effectively creating a hodge-podge of policies, resulting in a range of standards for the testing of autonomous vehicles (largely pertaining to autos) and even for the level of autonomy those vehicles are permitted on public roads (most permit Level 3, which requires some human operation, but some permit Level 4 and Level 5). So far, at least 21 states allow automated vehicles to be tested on public roads.

In September 2017, the House passed the SELF DRIVE Act, which enables the US National Highway Traffic Safety Administration (NHTSA) to expand the number of self-driving cars permitted to be tested on the roads from the current 2,500 to 100,000. A Senate vote is pending (at the time of publication of this report). The Act, if approved, would be the first federal law regulating automated vehicles and would open the door to much more testing of self-driving cars.

Meanwhile,the Senate has its own autonomous-vehicles proposal, known as the AV START Act, which has yet to be brought to a vote (as the publication of this report.)[19]

When a plastic bag…is just a plastic bag

You can build a self-driving car in a weekend, but under which conditions will it be able to operate? The world is extraordinarily complex. Can it operate in such a world? We are figuring out decision-making algorithms, building neural nets, but there will always be more new information to add to these neural nets, and getting machines to learn as well as they need to will be an enormous undertaking. For example, consider all the unpredictable events that occur when you drive a car. To an autonomous vehicle, a black plastic bag flying out the window of a truck in front of you could indicate a real danger. To a human driver, it's just a plastic bag.

—Tim Harris, CEO, SwiftNav, in an interview with PwC

The bill as it currently stands, however, excludes the piloting of self-driving heavy-duty trucks. "I expect that lawmakers will pass legislation on autonomous heavy-duty trucks eventually, perhaps by amending the SELF DRIVE Act or AV START before passage, but more likely through a stand-alone piece of legislation that also addresses some of the challenges of displacing human drivers," said Greg Rogers, policy analyst, ENO, in an interview with PwC. "As autonomous cars hit the roads in significant numbers, and people become more comfortable with the concept of self-driving vehicles in general, public acceptance of autonomous trucks will increase," Rogers added.

The US Department of Transportation released, also in September 2017, new guidelines on automated driving systems to help harmonize efforts around the development and testing of autonomous-vehicle technology carried out by a host of stakeholders, including industry, and state and local governments.[20]

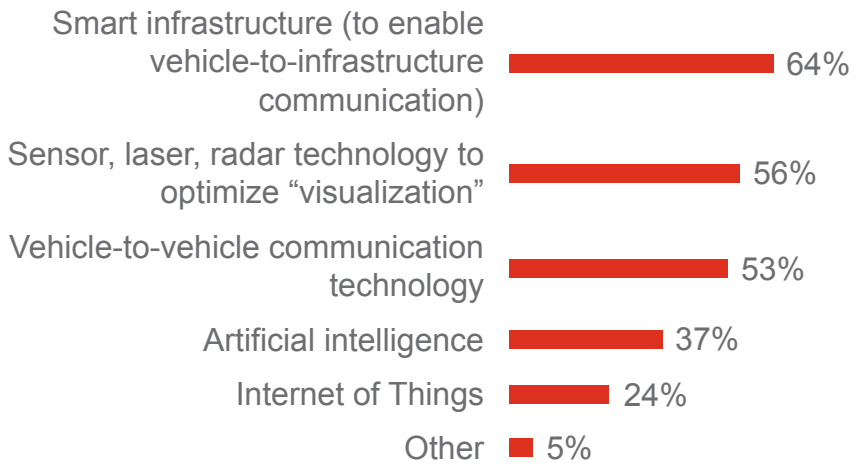
Smart vehicles need smart infrastructure. As trucks—and autos, trains and ships—rise up the autonomy maturity curve, smart transportation infrastructure will also need to take place on parallel tracks—most notably vehicle-to infrastructure (V2i) communications, including fitting roads, tolls, weighing stations, bridges, locks and docks, for example, with V2i technology. Ohio, for example, has earmarked $15 million to install fiber optic cable and sensor systems in roads. GM is currently piloting—with Michigan's Macomb County Department of Roads—vehicles that receive data from traffic lights, alerting drivers of a potential moving violation.[21] Presently, such pilots are focused on autonomous passenger vehicles.

Maintenance, expansion and modernization of the US transportation infrastructure investment rises has become an increasingly important issue. The American Society of Civil Engineers (ASCE), for example, grades the US highway system a "D" and estimates a backlog of $836 billion in highway and bridge capital funding. Going forward, there will be a greater need for investment in existing and new transportation infrastructure to include embedding V2i technology to future-proof the national surface and air transportation network.[22]

According to our survey, US manufacturers believe investing in "smart infrastructure" is the most important technological initiative needed to operationalize autonomous transportation of goods—followed by sensor, laser and radar technology, vehicle-to-vehicle technology and artificial intelligence.

Smart infrastructure seen as most important technology for fully autonomous freight transport

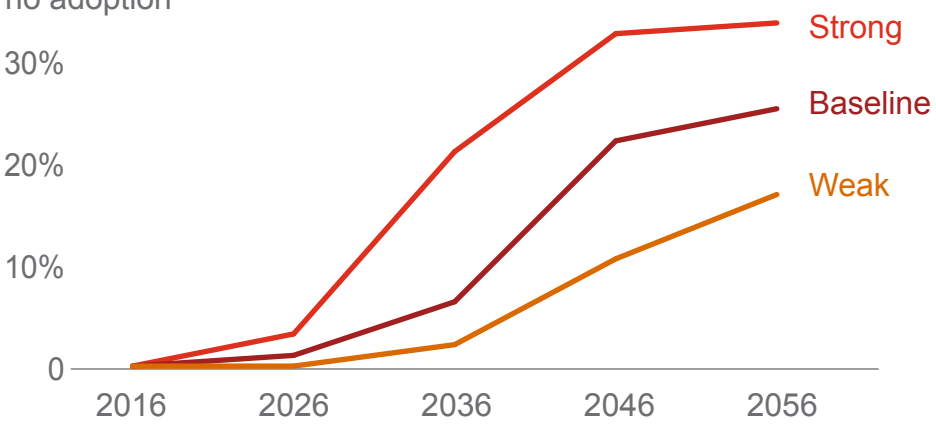
Q. What technology investments does your company believe are most important in order to operationalize fully autonomous transport of goods? (Note: choose all that apply.)



Respondent number: 78
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Aggressive automated trucking could cut manufacturers' trucking costs by nearly 30% by 2040

Estimated potential savings, as % of long-haul total trucking costs, via autonomous long-haul trucking adoption pace versus no adoption



Weak Adoption: Assumes rapid adoption beginning 2035 and nearing a long-term level of 40% adoption by 2050

Baseline Adoption: Assumes rapid adoption beginning in 2030 and nearing a long-term of 60% adoption by 2045

Strong Adoption: Assumes rapid adoption beginning in 2025 and nearing a long-term of 80% adoption by 2040

Source: PwC analysis, including estimates on manufacturing trucking costs from American Trucking Associations and The American Transportation Research Institute. For further information, please consult the methodology section of this report.

How could autonomous trucking cut transport costs? A PwC analysis

While this report explores all modes of advanced mobility (and mobility services), trucking is the dominant mode of freight transport. So, looking ahead, what could be the possible potential impacts on transport for manufacturers deploying autonomous trucks?

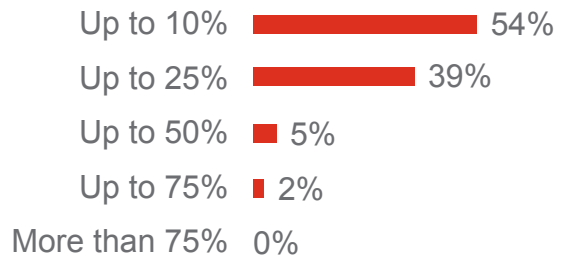
According to a PwC analysis, we found that, based on assumptions on how the future could play out, manufacturers could trim trucking costs by nearly 30% by 2040, assuming an aggressive adoption of automated trucking versus a no-adoption scenario.

Interestingly, survey respondents' estimates on trucking costs savings from autonomous trucking were in the same ballpark, with more than half predicting savings of up to 10% of total trucking costs, and about four in ten estimating up to 25% cost savings.

These findings also fall in line with a separate 2016 PwC/Strategy& analysis, which found that, depending on the degree of embedded automation and autonomy, "digitalized trucking" could lower the operating costs of a long haul truck by 15% (by 2025) and 28% (beyond 2025).[23]

About 50% of manufacturers see double-digit savings in transport costs via self-driving trucks

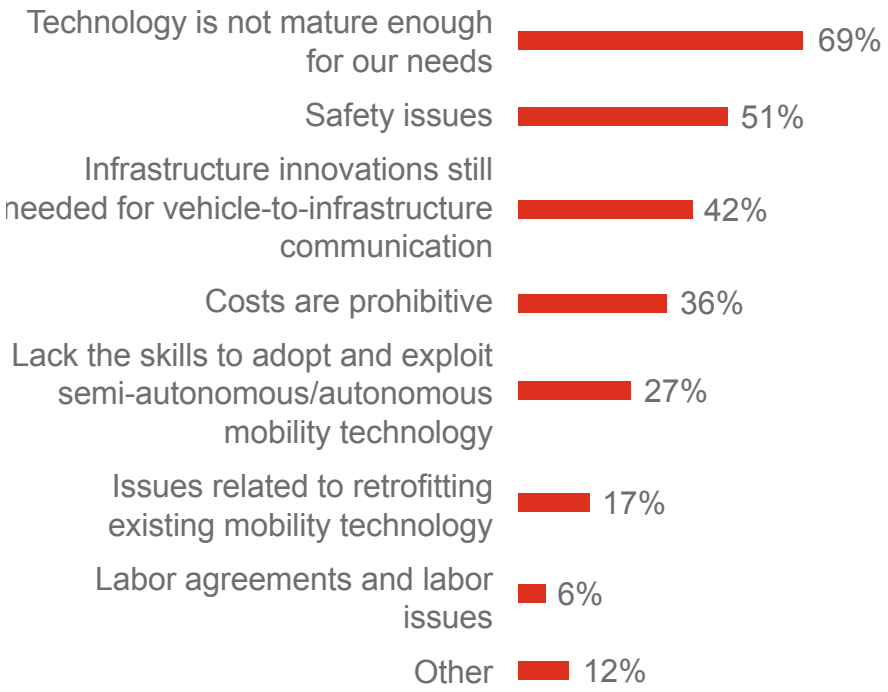
Q. How much would you roughly estimate your company would save, as a percentage of your total trucking costs (e.g., insurance, fuel, other efficiencies) if you adopted autonomous trucking (self-driving trucks)?



Respondent number: 57
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Immature technology, safety issues lead perceived barriers-to-entry for self-driving trucks deployment

Q. What are the barriers to entry or adoption of autonomous trucking (self-driving trucks)? (Check all that apply.)



Respondent number: 89
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Speedbumps for self-driving trucks adoption? While US manufacturers do see potential benefits that self-driving trucking could bring, there are still considerable perceived barriers to adoption. According to our survey, technology maturity falling short of transportation needs is the most common barrier, followed by safety issues and the need for infrastructure innovations still required for vehicle-to infrastructure communication. These barriers are followed by costs and lack of talent.

UAVs in the field…and beyond. While deployment of UAVs within facilities holds promise (as described earlier in this report), their adoption among manufacturers outside the manufacturing facilities remains uncertain.

Potentially, though, as UAV technology matures and if future FAA regulations encourage wider commercial use of UAVs, adoption rates could rise and applications widen. For example, UAVs could increasingly take on cargo-carrying and surveillance tasks traditionally carried out by helicopters and other aircraft. They are already being deployed for real-time monitoring surveillance by industries as diverse as insurance, mining, construction, agriculture and energy. And, as their payloads increase, they could disrupt how goods and materials are transported outside the factory.

Rail and marine freight transport: A new era of autonomy? US rail freight (which includes 140,000 miles of track) represented 9% of all domestic freight shipments in 2015.[24, 25] Yet, according to our survey, some 60% of manufacturers believe that greater levels of autonomy in freight rail would yield the greatest overall savings to their supply-chain costs, when compared to air or marine freight. While these modes represent a relatively small slice of cargo shipping, they, as with other modes covered in this report, could very well be on the cusp of a renaissance as degrees of autonomy are introduced. Indeed, autonomous technologies, particularly Positive Train Control (PTC), are already being rolled out in both passenger and freight rail in the US. PTC uses automated communication- and processor-based technology to help prevent train collisions, derailments and other accidents.[26]

For some time, however, much of the rail freight automation has been rolled out outside the US, such as London's Docklands Light Railway or Rio Tinto's $518m AutoHaul project, billed as the first fully autonomous, heavy-haul, long-distance railway system, which is being built to haul iron ore from Australian mines.[27]

A new age for non-road transport?

Q. Looking to other modes of transport, which ones—as they realize greater levels of autonomy and other efficiencies and advancements over the next decade—do you expect will result in the greatest cost savings to your company's supply-chain operations? (Please choose all that apply.)

Respondent number: 75
Source: PwC/Manufacturing Institute Industrial Mobility Survey

Some 600 million tons of cargo are transported annually on 25,000 miles of navigable inland waterways in the US. Yet, the American Society of Civil Engineers (ASCE) grades the system with a "D" grade, hobbled by decades-old docks and chronic delays.[28] Manufacturers in our survey seem to agree that there is much room for improvement. About one-third say that introducing greater autonomy in marine/ocean freight would result in the greatest costs savings in their supply-chain operations.

"Automating marine freight is a big opportunity—to save on labor costs with sailors, introduce efficiencies and improve safety," said Greg Rogers, policy analyst with ENO, in an interview with PwC. "Our inland waterways are not well-developed and are underutilized. We could very well see a renaissance in marine shipping if it can be automated. We've lost sight of how waterways can be optimized," Rogers added. Rolls Royce, for example, has initiated a research and development program to develop and test autonomous shipping.[29]

Industrial mobility and the talent quandary

Apart from the prospective efficiencies, cost savings and even increased safety surrounding autonomous vehicles of all stripes, it is important to consider the societal and workforce ramifications of a world of mainstreamed autonomous mobility. Consider the US trucking industry, which employs some 3.5 million truckers and generates $726 billion in revenues, according to the American Trucking Associations.[30] We may be moving to a greater need for a new generation of autonomous logistics experts to support the vehicles, overseeing fleets remotely, rather than physically operating them. Or, in the case of platooning, there may be a driver in the lead truck, but no drivers in the following trucks.

We may be moving to a greater need for a new generation of autonomous logistics experts to support the vehicles, overseeing fleets remotely, rather than physically operating them.

Some manufacturers may well encounter a lack of skills within their workforce to fully exploit autonomous vehicles within their operations. Indeed, the learning curve will likely rise for drivers and operators as they become accustomed, by degrees, to driver-assisted technology (already the case with some forklifts, for example). Also, those manufacturers adopting semi-autonomous and autonomous vehicles will likely do so over years, and will likely therefore need a talent strategy that will best leverage that adoption. With this in mind, some workforce skills new adopters will likely need to focus on include: safety skills, new work flows and software programming, as well as specialized training from vehicle vendors.

Executive leadership leads decision-making on new mobility adoption

Q. Who is handling the evaluation and decision making related to the adoption of advanced industrial mobility technologies? (Note: Respondent may choose more than one.)

Respondent number: 95
Source: PwC/Manufacturing Institute Industrial Mobility Survey

It is interesting to note that mobility decisions are made by executive leadership by nearly three of four manufacturers in our survey. Because decisions could have important implications for those across the organization, it could prove useful for companies to draw on the knowledge and insights from a multitude of players to arrive at most well-informed decisions. For example, companies could enlist the insights and knowledge from a host of employee (and external) ranks, including, for example: plant management, outsourced transportation/logistics firms, engineering and strategy, chief technology officer or chief information officer.

IV Where do you fit in? An industrial mobility self-assessment

IV Where do you fit in? An industrial mobility self-assessment

As manufacturers and their supplier networks march up the industrial mobility maturity curve, they are likely to encounter numerous weighty and defining decisions—not only about return on investments, but also decisions that could affect safety, workforce preparedness and training, and even ethical decisions.

Indeed, the US industrial mobility ecosystem will evolve in the coming years, but will likely be built out incrementally—and even in a geographic "patchwork," growing in some areas faster than in others, as discussed in this report. As with any disruptive emerging technology, it's tricky to know just how and when it will play out.

Below are a few questions manufacturers may consider as they explore how and why they might fit into the industrial mobility ecosystem—and what they might do now to prepare for what may come down the road.

	Question Response			Applicability / Relevance		
	No	Partial	Yes	Low	Medium	High
Building Internal Awareness						
Do you have a designated role(s) assigned to developing and deploying the adoption of advanced industrial mobility?	☐	☐	☐	☐	☐	☐
How broadly across your organization do you currently reach (or plan to do so in the future) to solicit input on evaluating and decision-making surrounding industrial mobility?	☐	☐	☐	☐	☐	☐
Exploring Business Benefits						
Have you explored what kinds of costs savings (e.g., labor, health insurance, efficiencies) your company might experience through industrial mobility (mobile robots, unmanned aerial vehicles) within your operations?	☐	☐	☐	☐	☐	☐
Have you identified tasks/operations within your facilities that are prime candidates for semi-autonomous and fully autonomous vehicles?	☐	☐	☐	☐	☐	☐
Have you worked with your logistics vendors and/or your in-house logistics and transportation team to explore how autonomous freight transport could affect your business?	☐	☐	☐	☐	☐	☐
Have you considered small, do-able pilots within your operation to test industrial mobility technology to ensure it is right for you?	☐	☐	☐	☐	☐	☐
Workforce Considerations						
Have you considered the impact semi-autonomous/autonomous vehicles may have on your workforce—for example, surrounding safety matters or upskilling and/or talent recruitment initiatives?	☐	☐	☐	☐	☐	☐
What are you doing now to prepare your workforce to adopt industrial mobility within your operations to ensure safety and fully leverage the technology?	☐	☐	☐	☐	☐	☐
Have you considered adopting semi-autonomous industrial mobility technology as a hybrid solution to prepare your workforce for fully autonomous vehicles (e.g., forklifts which require an operator yet have some autonomous functions)?	☐	☐	☐	☐	☐	☐
Has your company thought through the societal implications of driverless vehicles that make decisions based on algorithms—and not human judgment?	☐	☐	☐	☐	☐	☐

Endnotes

1 The US Bureau of Transportation Statistics: //www.bts.dot.gov/bts-publications/freightfacts-and-figures/freight-facts-figures-2017-chapter-2-freight-moved

2 "Automated Material Handling Equipment by Product—Global Market Forecast," press release, researchandmarkets.com, July 2017.

3 "Robot Nation: Warehouses promised lots of jobs, but robot workforce slows hiring," Los Angeles Times, December 4, 2016.

4 US Department of Labor/Bureau of Labor Statistics website: https://www.bls.gov/news.release/ecopro.t04.htm)

5 "World Robotics 2017," International Federation of Robotics, 2017.

6 "Globally Reach US $18,774.0 Million by End of 2021: A to Z Research," Digital Journal, October 31, 2017.

7 "Robotics in Logistics," DHL, 2016.

8 "This Autonomous Forklift Wants to Eat Up Warehouse Jobs," MIT Review, August 22, 2017.

9 "Drone market shows positive outlook with strong industry growth and trends," Business Insider, July 13, 2017.

10 U.S. Department of Transportation, Bureau of Transportation Statistics, Freight Analysis Framework, Version 4.3.1, 2017.

11 U.S. Department of Transportation, Bureau of Transportation Statistics, Freight Analysis Framework, Version 4.3.1, 2017.

12 US Bureau of Transportation Statistics website https://www.bts.dot.gov/bts-publications/freight-facts-and-figures/freight-facts-figures-2017-chapter-2-freight-moved

13 "How automated driving tech will impact commercial trucking," law360.com, Nov. 10, 2016.

14 "Uber's self-driving truck makes its first delivery: 50,000 beers," wired.com, October 25, 2016.

15 "How one company is harnessing the technology behind driverless cars to launch the autonomous train revolution," smartrailworld.com, April12, 2017.

16 "Tesla Semi revealed: Electric truck is semi-autonomous, has 500-mile range," techrepublic.com, November 17, 2017.

17 "And just like that, platooning is here," Fleet.com, April 7, 2017.

18 "Federal Highway Administration Showcases Cutting-Edge Truck Platooning Technology," US Department of Transportation, September 14, 2017.

19 "5 Federal AV Policy Developments to Watch in 2018", ENO Transportation Weekly, January 12, 2018.

20 "US DOT releases Automated Driving Systems guidance," National Highway Traffic Administration, September 12, 2017.

21 "Michigan road agencies and General Motors R&D division are collaborating in the connected and automated vehicle space by demonstration smart signal technology," enterpriseinsights.com, June 16, 2017.

22 "2017 Infrastructure Report Card," American Society of Civil Engineers, 2017.

23 "The era of digitalized trucking," PwC/Strategy&, 2016.

24 Bureau of Transportation Statistics: https://www.bts.dot.gov/bts-publications/freightfacts-and-figures/freight-facts-figures-2017-chapter-2-freight-moved

25 Generating $274 billion in 2014, freight railroad remain a pillar of the US economy," smartrailworld.com, August 10, 2016.

26 US Department of Transportation/Federal Railroad Administration website, https://www.fra.dot.gov/ptc

27 "Are driverless freight trains safe?" www. railwaytechnology.com, September 26, 2016.

28 "2017 Infrastructure Scorecard: Inland Waterways," ASCE, 2017.

29 "Rolls-Royce moves ahead on autonomous ship R&D," www.marinelog.com, March 8, 2017.

30 ATA website: http://www.trucking.org

Methodology

Effect on automated trucking on total trucking costs

PwC estimated savings in manufacturers' long-haul trucking costs were based on assumptions of how automated trucking could affect trucking cost items including drivers/operators, fuel, truck/trailer lease purchase payments, repair and maintenance, truck insurance premiums, tires, tolls, permits and licenses.

This model uses a baseline estimate—that long-haul trucking costs for manufacturers account for 14% of US manufacturers' total manufacturing costs—by The American Trucking Associations ("Trucking Industry Revenues were $676.2 billion in 2016," ATA press release, August 14, 2017) and IHS historical and forecast manufacturing revenue data.

The model also uses baseline estimates of the percentage contribution of each cost item (mentioned above) to total long-haul trucking costs estimated by The American Transportation Research Institute (ATRI-"An Analysis of the Operational Costs of Trucking: 2016 Update," 2016.)

Acknowledgments

PwC and The Manufacturing Institute would like to thank the following interviewees for their time, care and insights:

Jeff Burnstein, President of the Association for Advancing Automation

Greg Rogers, Policy Analyst at the Eno Center for Transportation

Tim Harris, CEO of Swift Navigation

To have a deeper conversation about how this subject may affect your business, please contact:

Bobby Bono, Partner, Diversified Manufacturing Leader
(813) 222-7118
robert.b.bono@pwc.com

Andrew Tipping, Principal, Enterprise Strategy
(312) 298-4916
andrew.tipping@pwc.com

Todd Benigni, Principal, Operations Consulting
(312) 298-3192
todd.m.benigni@pwc.com

Frederick Duiven, Director, Enterprise Strategy
(703) 682-5597
frederick.duiven@pwc.com

Brandon Mason, Director, US Mobility Leader
(313) 394-6098
brandon.w.mason@pwc.com

Adam Wisniewski, Director, Drone Powered Solutions (PwC Poland)
+48 22 746 4000
adam.wisniewski@pwc.com

From the National Association of Manufacturers:

Chad Moutray, Chief Economist, cmoutray@nam.org

Editorial team:

Chris Sulavik, Senior Fellow, US Thought Leadership Institute

Craig Scalise, Senior Fellow, US Thought Leadership Institute

Tom Waller, Director, US Industrial Products

© 2018 PwC. All rights reserved. PwC refers to the US member firm or one of its subsidiaries or affiliates, and may sometimes refer to the PwC network. Each member firm is a separate legal entity. Please see www.pwc.com/structure for further details. 407467-2018 CT PT