A Work Project, presented as part of the requirements for the Award of a Master's degree in Management from the Nova School of Business and Economics.

The Impact of Autonomous Driving in the Trucking Ecosystem

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Abstract

Autonomous trucks have a great potential to be the first transport application of autonomous driving in the U.S., due to easier road navigation, operational benefits and a driver shortage. As trucking is the dominant mode of freight transportation in the country, the full adoption of autonomous trucks could save $87.57 billion in driver wages per year and create an excess fleet situation, with 2.36 million trucks at risk to become obsolete. This would have implications for the value chain stakeholders, specifically drivers, owner-operators, OEMs and suppliers, creating new business models and a different freight distribution network.

Keywords (Autonomous Driving, Autonomous Trucks, Freight Transportation, Value Creation, Market Research)

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Chapter 2 Agenda

Structure

2 Autonomous Trucks — **The Impact of Autonomous Driving in the Trucking Ecosystem**

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2.1.3. Trucking Value Chain
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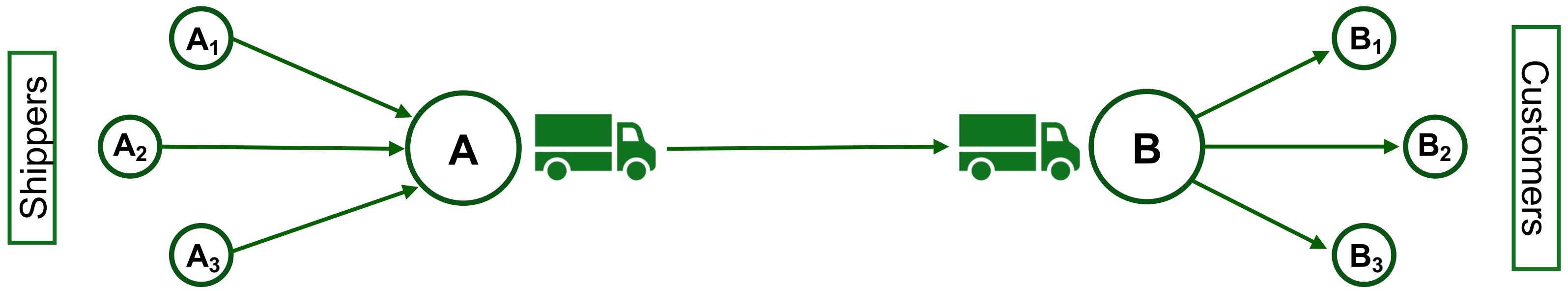
Trucking is a pillar of the U.S. economy, being the dominant mode of freight transportation both by value and weight

Common topology of freight distribution networks

2.1

To get a shipment from Point A to B, the cargo owner typically outsource distribution logistics operators. The cargo is moved from a factory in an urban area and delivered to an out-of-town hub (A), where it will be loaded for **hub-to-hub transportation** (H2H), through several possible modes of transportation: **truck, rail, water, pipeline, air or other**. The last phase takes place from the hub (B) to the urban distribution centres, and then to the customer's address.

First Mile | Hub-to-Hub | Last Mile



Trucks carry more freight than all other modes combined (rail, water, pipeline and air)

Value	Transportation revenues in the U.S. were estimated at $1 trillion in 2018, including trucks, rail, water, pipeline and air. During this period, the trucking industry had over **$796.7 billion** in revenues, accounting for **80.3%** of total freight revenues (Exhibit 1).
Weight	In 2018, trucks moved **11.1 billions tons** of freight domestically, representing **67.5%** of all domestic freight movements. (Exhibit 2).

Source: American Trucking Associations; U.S. Department of Transportation; Bureau of Transportation Statistics;

The trucking industry is very fragmented, and the hub-to-hub segment employs 1.8 million truck drivers operating almost 4 million heavy-trucks

Industry Overview

2.1

Employment	There are 13.3 million transportation-related jobs, accounting for 9.1% of all U.S. workers. There are approximately 3.6 million truck drivers in the U.S., being the primary occupation in over half of all U.S. states. In the **Hub-to-Hub** segment, there are **1,797,710 drivers**, earning a mean hourly wage of **$23.42**.
Industry Competitiveness	The trucking industry structure is composed by fleets and independent owner-operators. The industry is extremely competitive due to its **fragmentation**, with 91% of all operators have fewer than 10 trucks. Only 1% of operators have fleets larger than 100 trucks, while owner-operators account for 50% of all operators (Exhibit 3).
Top Commodities	The patterns of production and consumption in the U.S. are the main drivers to determine which commodities are transported. By value, **Mixed Freight**, **Electronics** and **Motorized and other vehicles** are the top commodities moved by truck (Exhibit 4). By tonnage, **Gravel and crushed stone**, **Non-metallic minerals** and **Cereal Grains** are the top three commodities (Exhibit 5).
Trucks	In 2019, there were 158.4 million trucks registered in the U.S. (Exhibit 6), from which 36.9 million are used for business purposes. From these trucks, there were approximately **3.91 million** Class 8 trucks (Exhibit 7) operating in the U.S. From 2011 to 2019, truck production grew at a 4,5% CAGR (Exhibit 8). Freightliner is the largest producer (36% market share).
Mileage	Trucks travelled over **300 billion miles** in 2019 (Exhibit 9), representing 9.2% of total miles driven by all vehicles in the U.S. Single-unit trucks travelled 125 billion miles, while combination trucks (more than one trailer) travelled 175 billion miles. The average number of miles driven by heavy trucks is **93,955 miles per year**.
Freight Corridors	The most valuable corridors are concentrated between the major metropolitan areas (Exhibit 10), with 79% of all freight flows being concentrated on 10% of the country's interstate highways. The most valuable freight corridors are **New York to Philadelphia** ($56 billion), **Los Angeles to Riverside** ($51 billion), and **San Francisco to San Jose** ($30 billion), among others.

Source: American Trucking Associations; U.S. Department of Transportation; Federal Highway Administration; Bureau of Labor Statistics; ATRI : An Analysis of the Operational Costs of Trucking, 2020;

Truck operators execute the physical link between companies and customers, being supported by logistics activities

Trucking Value Chain

2.1

Primary Activities

Truck Operators

Typically owner or fleet operators, who provide hub-to-hub freight transportation services, and node activities (loading/unloading). Resources: trucks and drivers.

Logistics Operators

Usually third-party logistics and freight forwarders, who arrange and coordinate freight transportation on behalf of customers. Resources: warehouses, relationships, information.

Shippers

Manufacturers, wholesalers or retailers that want to move their cargo from Point A to B.

Autonomous trucks can **substitute truck drivers**, generating **$87.57 billion** in wage savings. However, this would result in millions of jobs losses and would have implications across the entire ecosystem.

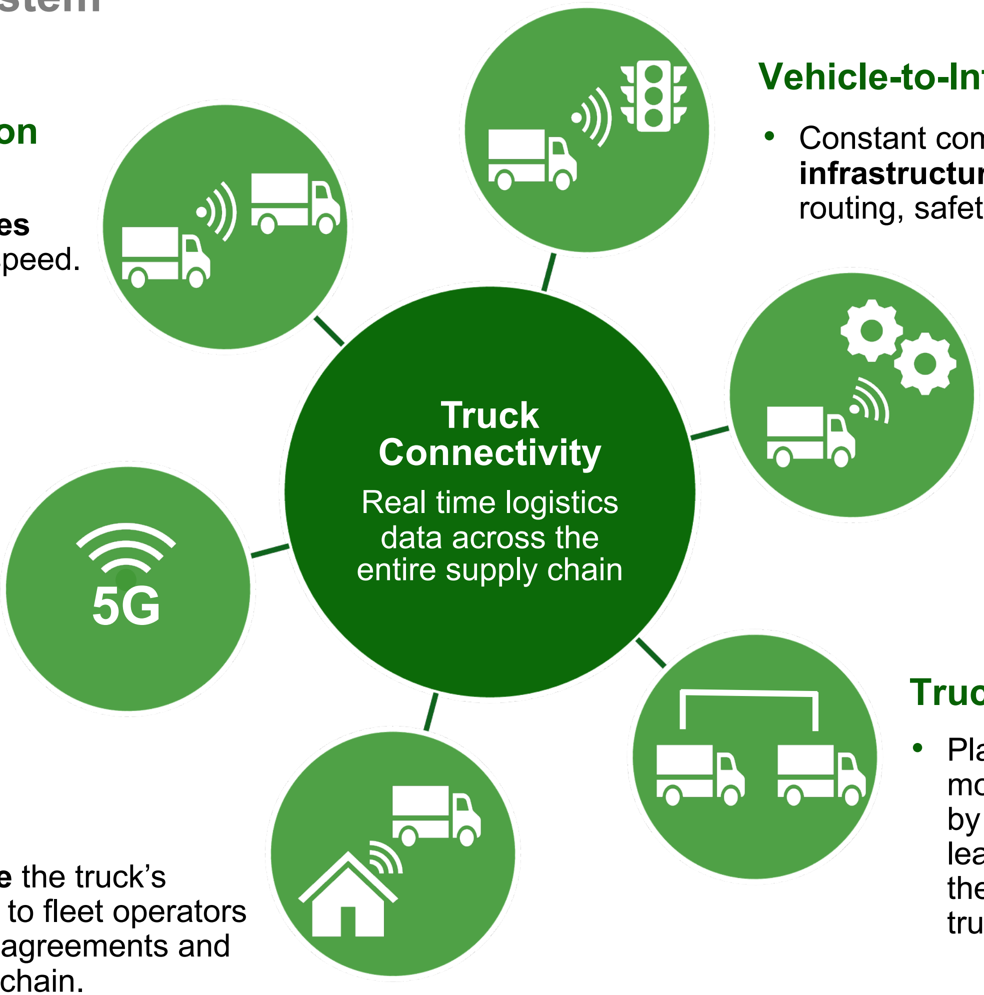
Secondary Activities

- **Original Equipment Manufacturers**
  - Design and assemble truck parts and systems supplied by Tier 1, such as powertrains, chassis and engines.
- **Leasing Operators**
  - Provide financing alternatives to truck operators.
- **Technology Companies**
  - Deliver truck connectivity systems, routing software and freight matching solutions
- **Insurance**
  - Provide protection for property, people and cargo from damage caused by the truck.
- **Infrastructure**
  - Highways, road and traffic signs charging stations, maintenance and repair shops.
- **Government**
  - Ensure safe and efficient freight transportation, through traffic laws and trucking regulations

Truck operations are immersed in a digital ecosystem, that is unlocking the full value of autonomous driving

Trends affecting the ecosystem

2.1



Vehicle-to-Vehicle Communication

- Intelligent telematics systems sharing information with **other vehicles** regarding the position, direction and speed.

Vehicle-to-Infrastructure Communication

- Constant communication with the **surrounding infrastructure**, such as smart traffic lights, improving routing, safety and traffic flow.

Remote Diagnostics

- Constant **monitoring of the truck's condition** through instant updates, allowing for maintenance efficiencies and less fleet downtime.

5G Technology

- As autonomous trucks need to make decisions and communicate them with other vehicles within a fraction of a second, 5G technology enables a faster connection through **lower latency**.

Truck Platooning

- Platooning consists of **interlinked** trucks moving together in highways, typically separated by 15 meters, that follow the behaviour of the leading truck. Given the inter-vehicle proximity, there is a **reduction in the air resistance** of the truck, improving fuel consumption.

Automated Freight Matching

- Sensors that **track and communicate** the truck's available capacity and route schedule to fleet operators and cargo owners, enabling real-time agreements and more transparency across the supply chain.

Hypothetically, with the full adoption of driverless trucks, the U.S. road transport system could go from a driver shortage to an excess fleet situation

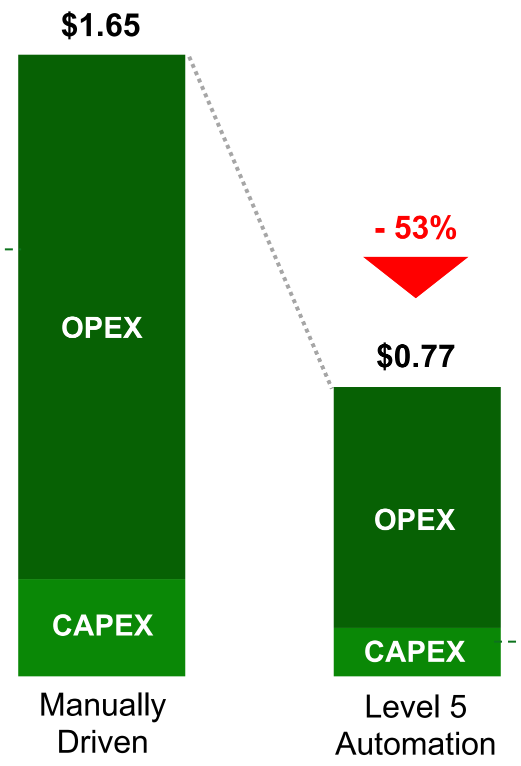
Major impacts of autonomous driving in the trucking industry

2.2

Operational Savings

- In the coming 10 to 15 years, artificial intelligence could be operating trucks on interstate highways, **replacing the driving task** performed by humans. This could alleviate the **shortage of truck drivers**, which is projected to reach 160,000 drivers by 2028.
- The adoption of this technology is largely driven by **operational savings**, whose main benefit is the removal of driver's salaries, the largest component of road freight transportation costs. In the hub-to-hub segment, this could result in **1.8 million jobs losses.**

Cost per Mile



Higher Truck Utilization

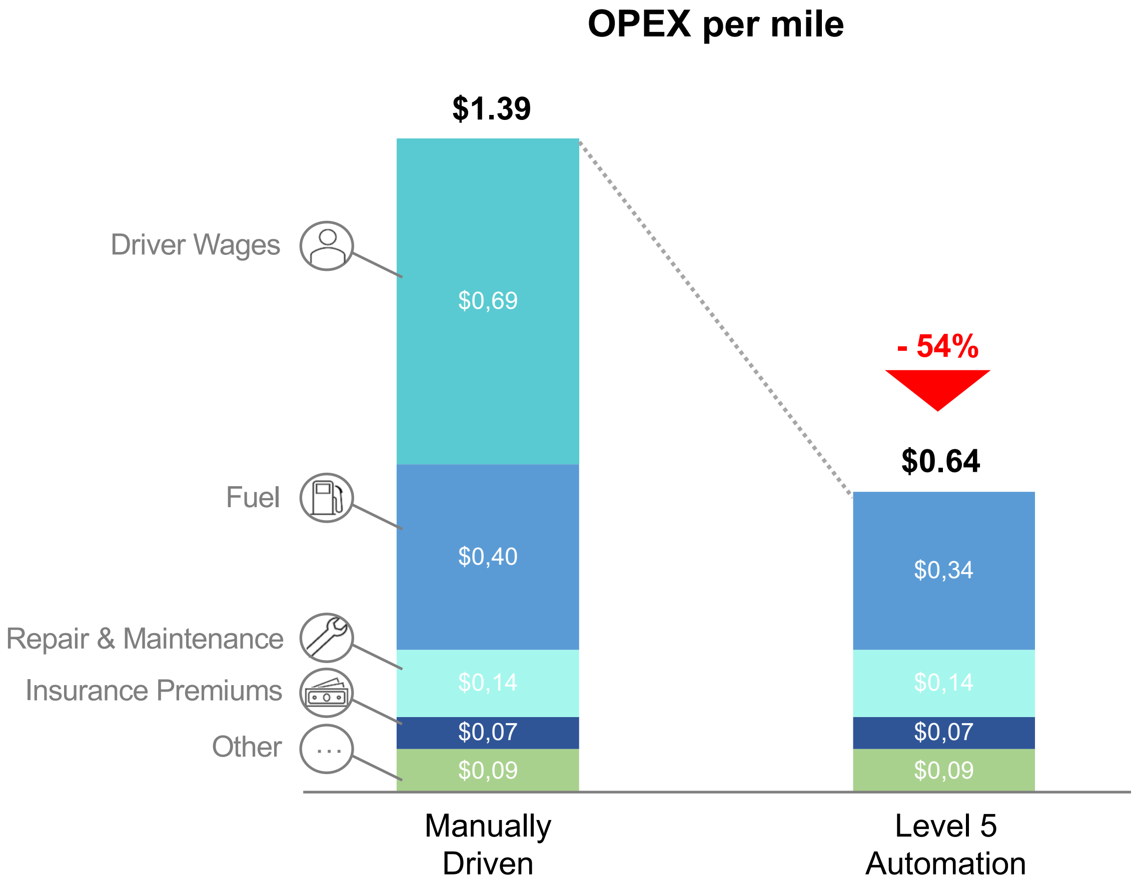
- Autonomous trucks are more efficient, driving up to **20 hours a day**. Consequently, the necessary **truck fleet required to carry today's freight volume would decrease**, making part of the existing 3.91 million trucks obsolete. Moreover, driverless trucks could mitigate the supply chain cyclicality, as they are not subject to the human calendar.
- To replace the unnecessary trucks, there are three available options: drive until the end of its useful life, dismantle the truck, as 75% of the asset can be recycled, or export it to developing countries as second-hand trucks.

Source: American Transportation Research Institute: An Analysis of the Operational Costs of Trucking, 2020; McKinsey: Distraction or disruption? Autonomous trucks gain ground in US logistics, 2018;

The largest direct cost-out effects from full autonomy derive from the elimination of the driver role and a smoother driving

2.2

Impacts on Operational Expenditure



Operational Expenditure Savings

Autonomous driving has significant impacts on truck carrier's operational cost structure, with driver wages and fuel costs being the most affected items:

- Automating the driving task could eliminate **driver wages**, which constitutes almost **50% of operational costs**. However, automation does not substitute all tasks performed by a driver, such as loading/unloading. Also, driverless trucks require qualified remote operators, whose wages should be higher.
- Fuel savings derives from two factors: more **fuel-efficient driving** from autonomous systems and aerodynamic-enabled fuel savings from **platooning**. The net effect is estimated to be between 10% to 20%.
- Other items in the heavy truck cost structure could be impacted by autonomous driving, such as maintenance or insurance. These effects will be explored in chapter 2.3.

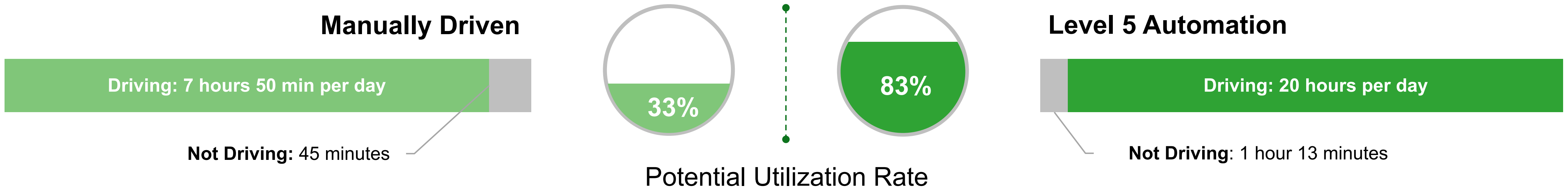
Level 5 automation could benefit fleet operators through operational savings. Nevertheless, automated freight matching platforms will enhance the **transparency** of freight rates and truck available capacity. Eventually, part of these operational savings could be transferred to the end customers, through **lower freight rates**.

Source: American Transportation Research Institute: An Analysis of the Operational Costs of Trucking, 2020; Roland Berger: Automated Trucks, 2016;

Autonomous trucks have no need to rest, which could alleviate the lack of driver hours supplied, currently limited by Hours-of-Service regulations

Impacts on Truck Utilization

2.2



Driving: 2860 hours per year

The Hours-of-Service regulations restrict the time that a truck driver can be on the road: up to 14 consecutive hours on duty, in which they are limited to **11 hours of driving time**, followed by 10 hours off duty.
The Electronic Logging Device mandate requires drivers to **record on electronic devices** their hours on duty and driving.

Driving: 7300 hours per year

Since autonomous trucks are not subject to HOS regulations, a truck could be in use from **18 to 20 hours per day**.
As a result, they will be more flexible, being able to travel **more miles** and transport **more freight**. Nevertheless, the useful life of a truck - 7 years - should decrease proportionally to the increase in truck utilization.

Not Driving: 275 hours per year

When a truck is on the road, it only stops to:
- **Load** (19 min) and **Unload** (31 min) in the hub -171 hours.
- **Maintenance** every 15,000 miles, 2 hours per repair - 21 hours.
- **Refuel,** tank capacity is 150 gallons and 30 min refuelling - 70 hours.
- **Cleaning** once a week - 13 hours.

Not Driving: 447 hours per year

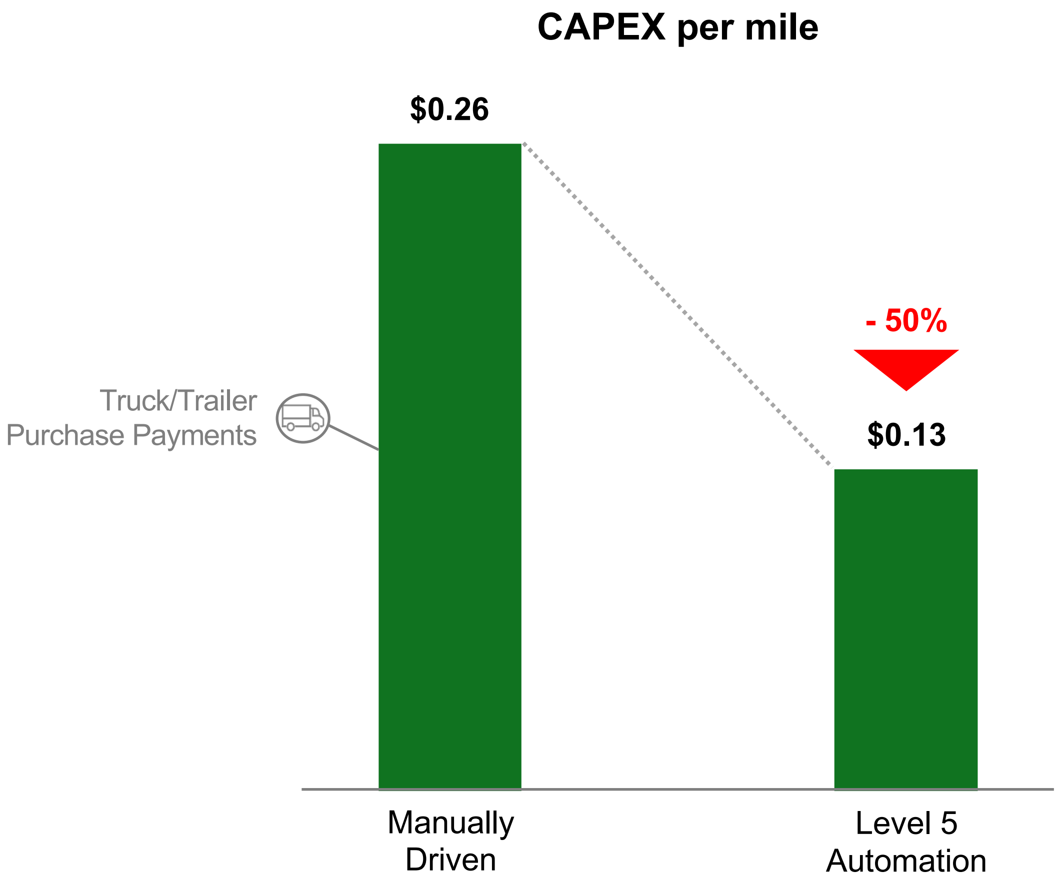
Likewise, autonomous trucks must stop to:
- **Load** and **Unload**, but they perform more trips - 257 hours.
- **Maintenance**, but they travel more miles - 54 hours.
- **Refuel**, assuming 20 min refuelling - 119 hours.
- **Cleaning** once a week - 17 hours.

Source: McKinsey: Distraction or disruption? Autonomous trucks gain ground in US logistics, 2018;

Due to efficiency gains from automation, the U.S. truck fleet could accommodate a higher demand

Impacts on Capital Expenditure

2.2



Capital Expenditure Savings

Autonomous trucks require a **higher initial investment**:

- Manufacturing cost of hardware components might fall, mostly due to the removal of the truck cockpit, decreasing the truck cost.
- The cost of driverless technology should increase the truck purchase price by 20% to 30%. Although uncertain, the cost for Level-5 automation is estimated at $23,400 per truck.

The net effect should be positive, and we assume the truck purchase cost to **increase by 25%,** increasing CAPEX.

Nevertheless, by increasing **the truck utilization**, the annual fixed cost related to the truck acquisition would be **diluted**, resulting in lower CAPEX per mile, as fewer trucks are needed.

As a result, to transport the same 11.1 billions tons of freight, it would only be required **1.55 million trucks**, resulting in an **excess fleet** situation. While freight volumes are estimated to keep growing (Exhibit 2), the fleet size needed to carry these volumes will likely decrease. Ultimately, these changes will depend on the adoption rate of autonomous trucks.

Source: American Transportation Research Institute: An Analysis of the Operational Costs of Trucking, 2020; Roland Berger: Automated Trucks, 2016;

The full adoption of autonomous trucks could save $87.57 billion in wages per year and reduce the U.S. fleet size by 2.5x

The size of the prize

2.2

If 100,000 driverless trucks were added per year to the U.S. truck fleet, it would take four years before autonomous trucks compose 10% of the entire fleet.

$87.57 billion
savings in wages

1.8 million drivers × 23.42 $/hour × 2,080 hours

 # 2.36 million
fewer trucks needed

33% Utilization → 83% Utilization

Although the potential value of autonomous trucks could reach these hypothetical values, the **adoption rate** of driverless technology will be **progressive** and **uncertain** (Exhibit 11), due to its structural **implications for society**, such as unemployment, congestion, pollution, and safety. The technology raises big questions regarding changes in the value chain and the distribution of these savings among its **stakeholders**.

Source: Managing the Transition to Driverless Road Freight Transportation, 2017;

Platooning could be a bridging technology in the adoption of autonomous trucks, driven by operational savings and fewer emissions

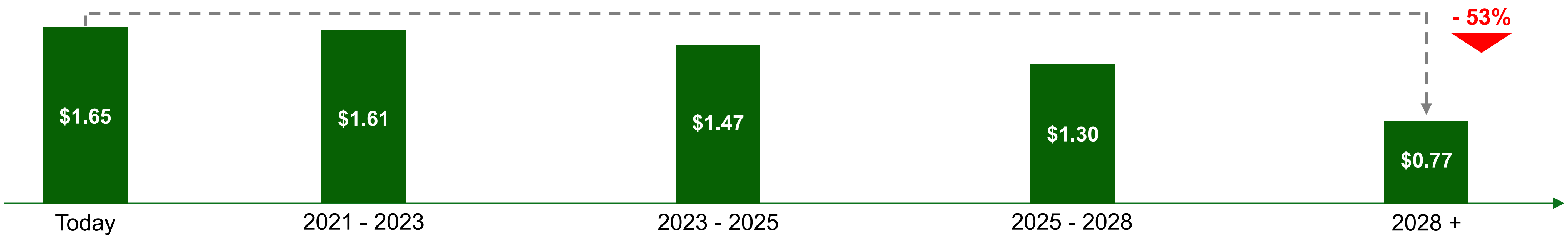
Stages of Adoption

2.3

To date, there is still considerable uncertainty of when will autonomous trucks emerge in the market. Recent studies estimated timelines for the technology penetration, ranging from 2025 to 2035, with minimum adoption rates for stage one and two.

Stage 1 No Automation	Stage 2 Partial Automation	Stage 3 High Automation	Stage 4 Full Automation
Trucks are manually driven, but on the highway, they could form platoons of 2-3 trucks.	Platooning only on highways with a driver in the leading truck. Trucks are subject to **V2V communications**. Off the highway, drivers take control of each truck.	Driverless trucks **operate only on highways**. Trucks are subject to **V2I communications**. Limited capabilities in conditions of low visibility (rain, fog or snow). The driver delivers the truck to the designated area.	Fully autonomous trucks operating **from loading until delivery**, forming platoons of 3 or more trucks on all highways. Driver's contribution is **fully substituted**.

Cost per Mile



Cost Drivers Changes	-10% Fuel	-10% Fuel -20% Wages	-10% Fuel -45% Wages	-15% Fuel -100% Wages

Source: International Transport Forum, 2017; ATRI - An Analysis of the Operational Cost of Trucking, 2020; McKinsey: Distraction or disruption? Autonomous trucks gain ground in US logistics, 2018;

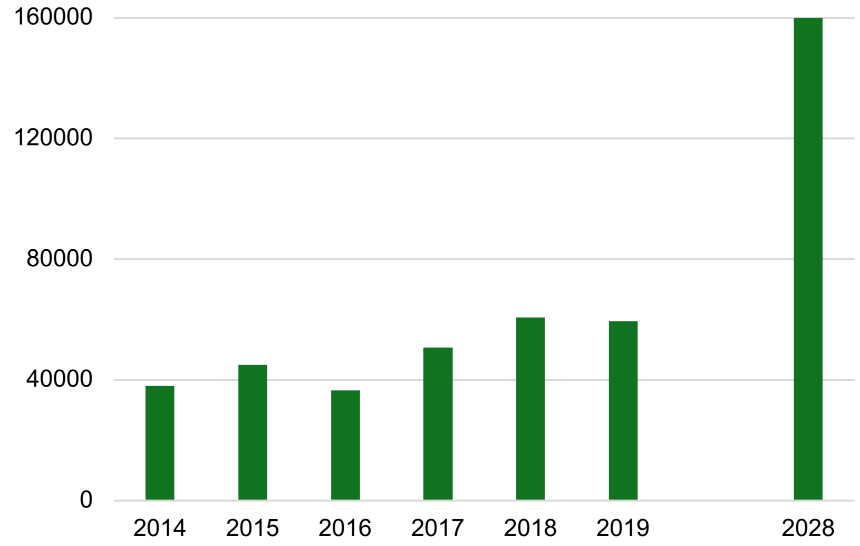
The emerging driver shortage in the U.S. could trigger the adoption of autonomous truck technology

Implications for Hub-to-Hub Drivers

2.3

There is a massive and aggravating shortage of truck drivers in the U.S.

- In 2018, the **demand** for heavy truck drivers **exceeded the supply** by **60,800 drivers**, increasing 20% from 2017. The American Trucking Associations estimates this shortage could rise to 160,000 by 2028, based on expected demand and retirement rates.
- This occupation struggles to attract women and young generations, with **demography the main cause** for the shortage, as the median age of a truck driver is 49 years old - 7 years older than the average U.S. worker. With an ageing driver population, retirement accounts for 54% of future drivers needed, as **they are not being replaced by younger people**. Likewise, female drivers comprise 6.6% of all truck drivers, representing a significant untapped share of the active population for the industry. Industry growth is the second main factor, accounting for 25% of future driver's needs.
- The bulk of truck driver shortage prevails in **hub-to-hub routes**, due to **difficult working conditions** – driving for long periods, without being able to stand and stretch, can arm driver's health.



This shortage has been triggering the growth of long-distance truckload prices

Driver hours are limited by Hours-of-Service regulations, which affects multiple industries, as trucking plays a key role in the U.S. freight transportation system. **Insufficient supply of driver hours is decreasing the available truck capacity** to shippers and delaying orders. Consequently**, long-distance truckload rates are increasing** (Exhibit 12), driving up the prices of goods due to higher transportation costs.

Source: Bureau of Labor Statistics**;** American Trucking Associations: Truck Driver Shortage Analysis, 2019;

Driverless trucks should reduce the demand for drivers at a faster pace than the shortage growth, increasing the risk for social unrest

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Implications for Hub-to-Hub Drivers

2.3

Partial Automation – Level 3 and 4

- Level 3 and 4 automation could **improve truck driving careers**, relieving the monotony of driving long hours and allowing drivers to rest or perform other tasks, which could result in higher driver retention. Moreover, autonomous trucks could incentivize young, tech-savvy generations to become truck drivers.

Full Automation – Level 5

- Although **full automation** could **replace drivers**, some operational tasks will still need the human as a core part. The new jobs created by driverless technology **will involve different skills** which involve sophisticated training, such as data analysis. Due to education levels, this will be **unfavourable for truck drivers** compared with the average American worker, who is more qualified (Exhibit 13).

Truck drivers can tap on the breaks of autonomous driving

The American transportation system is extremely dependent on trucks, moving **67.5% of all freight.** Autonomous trucks can dramatically shift trucking jobs, resulting in 1.8 million jobs losses. The **Teamsters labour union**, which represents more than 600,000 truck drivers, have been successfully pushing the Congress to **slow the adoption** of driverless trucks, claiming it will disproportionately threaten Latino and African-American truckers, due to their significant representation in truck driving jobs. The **threat of a social unrest** poses challenges for the country's political order.

If trucks stopped moving for one day...

… a **food shortage** would begin, as grocery stores would dry up their food stock; Hospitals would be at risk of running out of **basic supplies**, **fuel availability** at service stations would plummet, increasing fuel prices and generating long lines.

If trucks stopped moving for one week...

… the lack of fuel availability would cease **most forms of transportation**; the supply of **medical oxygen would run dry** and ATMs would run out of cash; Within two weeks, the **supply of clean water** would begin to run dry.

This transition needs to be managed by policymakers, considering the trade-offs of the high costs of job losses and the benefits of automation. Although there are increasing AV legislation (Exhibit 14) and public road testing, regulators should support this transition with appropriate measures to displaced drivers, such as **training opportunities, unemployment benefits and new jobs creation**. To ensure a smoother transition, the technology introduction should start on **less desired jobs**, such as highway routes unfilled by the driver shortage, who could work as a buffer to manage this transition.

Source: Bureau of Labor Statistics; American Trucking Associations;

For owner-operators, driver wages represent the largest cost item in truck operations and will be the most impacted by autonomous driving

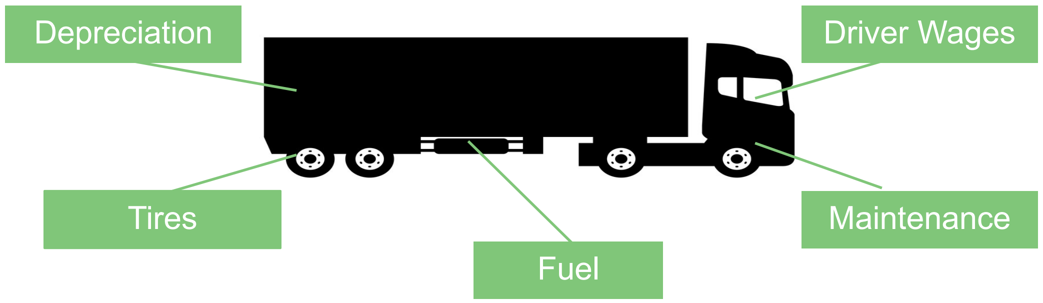
Implications for Owner-Operators

2.3

Methodology

- Self-driving trucks have the potential to change the owner operator's **cost structure** (see Exhibit 15 or the Excel file). We did not consider the cost-benefits for large fleet operators, to isolate the impact from scale economies. To estimate the cost impacts of the technology, we performed team calculations of an 80,000 pounds truck's **total cost of ownership**, to assess its lifetime (7 years) ownership costs.

Main Costs of Owning a Heavy Truck



Changes in Cost Structure Variables

- The standard truck cost model was based on 110,000 miles per year.
- The structural **cost drivers** were adjusted, based on **ranges**, according to different academic literature's perspectives, to reflect the **uncertainty** of the magnitude of autonomous driving effects.

Utilization Distance	[30%,70%]
Useful Life	[-30%,-70%]
Purchase Price	[15%,25%]
Driver Wages	-100%
Remote Operations	[3%,20%]
Fuel Consumption	[-20%,0%]
Maintenance	[-20%,20%]
Insurance	[0%,-20%]
Cleaning	[30%,70%]

To manage expectations and **uncertainty**, we developed **scenarios**, accessing plausible changes in factors shaping the future of owner-operators. Savings in the total cost of ownership range from 24% to 66% across the different scenarios, representing significant cost savings to manually driven trucks.

Sources: American Transportation Research Institute: An Analysis of the Operational Costs of Trucking: 2020; Bureau of Transportation Statistics; Bureau of Labour Statistics; Federal Highway Administration;

An autonomous truck can pay itself 4x faster than a conventional truck, and TCO savings could reach 47%

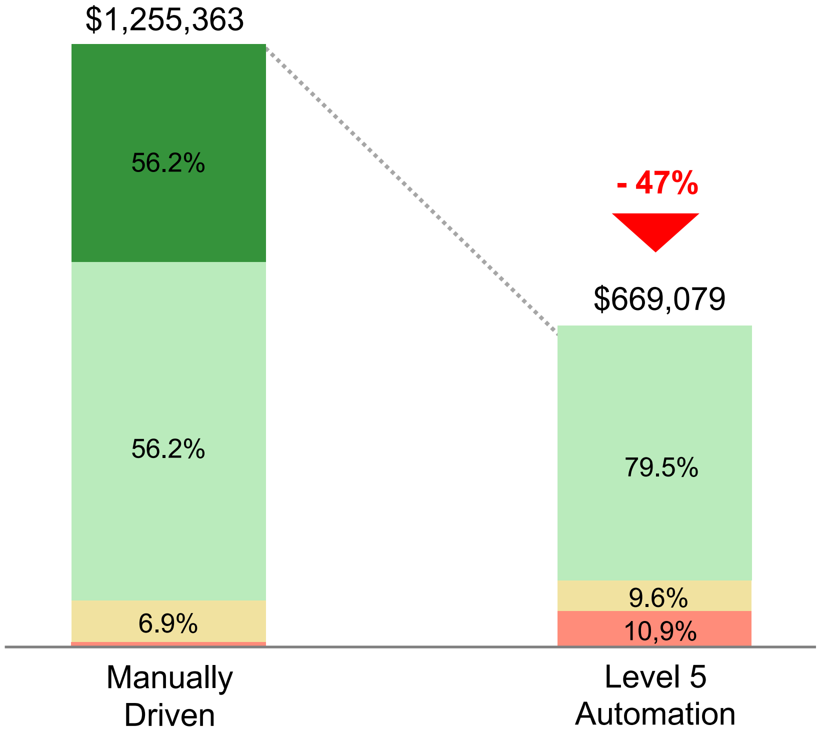
Implications for Owner-Operators

2.3

Changes in Variables

Drivers Wages	100%
Utilization	50%
Fuel Consumption	10%
Insurance	10%
Cleaning	50%
Useful Life	50%
Tractor Price	20%
Remote Operations	5%

Total Cost of Ownership



Manually Driven		Level 5 Automation
$1.63	**Cost per mile**	$1.16
1.43x	**ROI**	2.73x
70 months	**Payback Period**	17 months

Implications for truck's TCO

- As the driver is fully replaced, **fuel costs** become a major share of total costs (32%), signalling the attractiveness of electric trucks.
- The significance of **depreciation** costs rises by more than twice due to higher truck usage, representing 13% of total costs.
- Tires, tolls and maintenance costs are also affected by higher truck utilization.

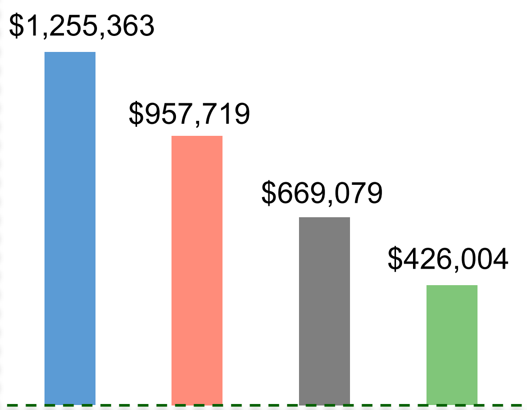
- There are no meaningful relative variations in the cost of cleaning, insurance, depreciation (ageing) and licenses.

- The new cost for **remote operations** represents 4% of the TCO, while **node costs** become a significant cost item (7%).

Compared with conventional trucks, driverless trucks enable significant cost savings in pessimistic, normal and optimistic scenarios

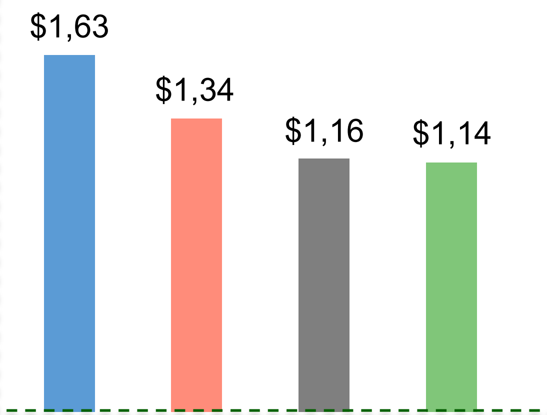
Implications for Owner-Operators

Total Cost of Ownership



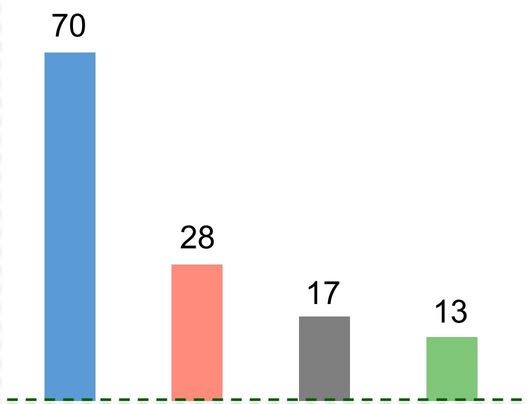
- This analysis provides a more complete perspective regarding the ”hidden” costs of owning a truck. Although it requires a higher initial investment, autonomous trucks create significant value in operational savings.

Cost per Mile



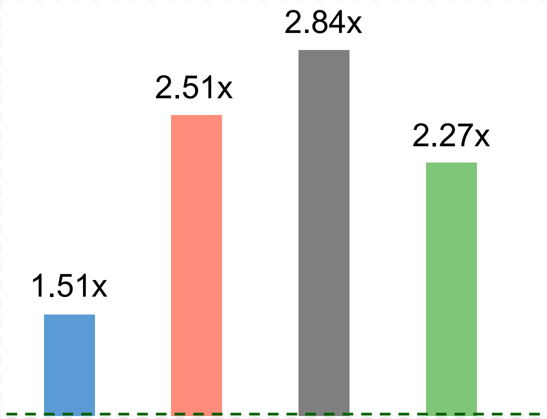
- The cost per mile calculated in chapter 2.2 differs from this one because this is an adjusted cost model that includes more variables.
- Still, there is a parallel reduction in the cost per mile, with this being less substantial, mostly due to the node cost and remote operations.

Payback Period (months)



- The annual utilization distance has the strongest effect on the payback period: the more miles the truck travels, the faster it pays itself.

Return on Investment



- In the normal scenario, EBIT increases by 8.3x, while the investment is only 1.15x higher.
- The optimistic scenario’s ROI is lower than the other scenarios because the truck travels more miles, having a shorter useful life. Hence, it generates lower returns over its lifetime.

Manually Driven Truck | Pessimistic | Normal | Optimistic

The adoption of autonomous trucks might lead to industry concentration, as larger companies are in a better position to exploit economies of scale

Implications for Industry Competitiveness

2.3

The increasing number of large fleet operators will be dictated by economies of scale. Nevertheless, operators focused on specialized transportation, such as radioactive cargoes, won't be so affected by industry consolidation, and should expect a stable demand.

Large investment	The acquisition cost of a first-hand Class 8 tractor-trailer is approximately $160,000. This is expected to increase, given the incremental price of driverless technology, estimated at $23,400 per truck. Larger fleet operators could **leverage their bargaining power** to lower the unitary truck price.
Platooning	Possibility to form efficient platoons by assembling a team of drivers to drive the trucks once they leave the highway. Larger operators can platoon **within their fleet**, while small operators are **less willing to platoon with competitors**.
Digital Infrastructure	If operating 20h per day, each driverless truck will require a **petabyte of data** in less than a week (4 terabytes of data per hour). Companies need to invest in software that sustains a **large amount of data** gathered, processed and shared.
Physical Infrastructure	Human drivers handle certain problems such as parking or maintenance control. Larger operators will need to invest in infrastructures, such as garages and maintenance shops, to **mitigate the lack of human involvement**.

Due to **cost-competitive advantages**, it will be easier for larger operators to deploy autonomous technology. Hence, they are likely to grow their market share by increasing market concentration. Smaller operators may not be able to reap the benefits of driverless technology, as they will face **price pressures** from larger fleet operators.

Source: Roland Berger: Automated Trucks, 2016; McKinsey: Distraction or disruption? Autonomous trucks gain ground in US logistics, 2018;

Currently, most of the value of a truck lies in the hardware: powertrain, cabin and chassis. Driverless trucks enhance the importance of software

Implications for OEMs and Components Suppliers

2.3

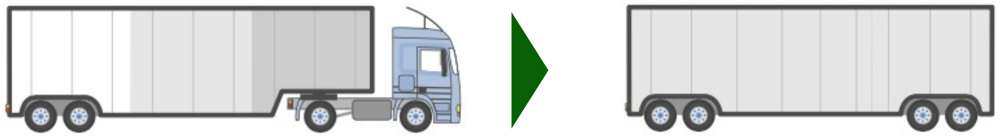
Powertrain - 40% to 45%

- Enhanced **engine emission control**, such as exhaust gas recirculation.
- Improved **steering systems:** a shift from mechanical to electric power steering due to improved ability for automated direction change.

Driver's Cabin – 25% to 30%

Design requirements will change from conventional trucks, as there is **no need to be driver-centric.** The **driver's cabin** will no longer be necessary, resulting in large cost savings, as it accounts for one-third of truck costs, due to its manufacturing complexity. Also, there will be **fewer safety features** in the truck, such as air bags or roll cages.

Conventional truck design | **Autonomous truck design**



Conventional truck design:
- High-efficiency powertrain
- Sophisticated cabin design
- Integration of ADAS features

Autonomous truck design:
- High-efficiency powertrain
- Capacity maximization
- Integration of ADS features
- Truck telematics

Chassis – 20% to 25%

- Improved **braking systems:** upgrade drum brakes to disc brakes technology, due to improved performance

Software - less than 5%

Improve current ADAS features (Exhibit 16) to **dynamic driving tasks**, enabling autonomous driving in the highway:

- Sensors (cameras, radar and lidar) allowing localization and **monitoring the truck's environment** and road users (Exhibit 17).
- Algorithm enabled machine-learning and AI are vital to the OEDR (object and event detection and response), replacing the **decision-making** process of truck drivers.
- Telematics systems to **gather and incorporate** freight and truck activity in the data flow.
- V2V and V2I communications to **share** truck speed, direction and location amongst vehicles and surrounding infrastructures.

With higher levels of automation, the complexity and connectivity capabilities of truck systems increases, and the value of trucks **will shift from hardware to software**. Although the development cost of software might increase, the incremental cost per additional unit sold approaches zero. Hence, the **marginal cost of producing a truck will fall**, generating higher margins. As software is difficult to replicate, there is an opportunity for software companies to capture a significant share of this profit pool.

Source: PwC - The Era of Digitized Trucking, 2018; Roland Berger: Trends in Truck Trailer, 2018;

Driverless technology will change the roles of suppliers and manufacturers, that are bounded to tight safety regulations and cyber-security concerns

Implications for OEMs and Components Suppliers

2.3

Original Equipment Manufacturers will focus on **retrofit existing trucks** and developing autonomous technology, due to their expertise in truck functionality. Although they rely on cost-competitive advantage, driven by organisational, manufacturing and financial capabilities, there are **high legal and technical costs of integrating Advanced Driving Systems in conventional trucks**.

Roles of **Component Suppliers**

- Develop cheap and safe **Advanced Driving Systems** (ADS)
- Manage the **interaction** between systems
- Improve **software and sensors** capabilities
- Develop **V2V** and **V2I** communication technology
- Improve **Predictive Powertrain Control** systems through high precision road maps

Roles of **Original Equipment Manufacturers**

- Holistically **define and integrate** software systems
- Provide **maintenance** for autonomous hardware and software
- Perform publicly available **safety simulations**
- Ensure that driverless trucks cannot be **hijacked**
- Guarantee full **system functionality** if a failure occurs
- Encourage ADS **acceptance** on consumers and regulator, due to potential fatalities and injuries reduction (Exhibit 18)
- **Train** drivers to operate on autonomous trucks (early stages)

To remain competitive, autonomous trucks manufacturers have to expand their product portfolio to comprise **safer steering and braking systems** and **diminish engine emissions**. Moreover, OEMs and suppliers have to reach consensus regarding the “rationale decision vs fair decision” ethical dilemma. If OEMs hold the liability for their driverless truck’s behaviour, they will be encouraged to **control its maintenance status** in real-time through remote diagnostics technologies.

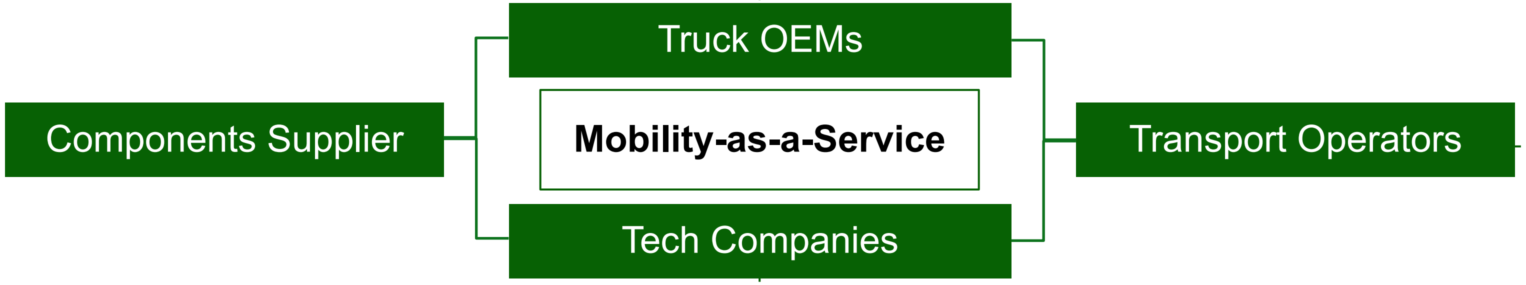
Source: PwC - The Era of Digitized Trucking, 2018; Roland Berger: Trends in Truck Trailer, 2018; ATRI: Identifying Autonomous Vehicle Technology Impacts on the Industry, 2016;

Truck OEMs and big tech companies have the opportunity to move upstream into logistics, resulting in greater fragmentation for transport operators

Possible go-to-market strategies

2.3

Due to technical capabilities, OEMs will keep manufacturing trucks, controlling the self-driving technology. However, instead of traditional truck sales, OEMs are well-positioned to offer **on-demand transportation solutions** to the market, by placing their trucks throughout major freight distribution clusters and designing a **subscription business model** based on hours or mileage. Ultimately, they could reinforce their role as mobility providers, by moving **upstream into the logistics chain**, competing with fleet operators and leasing companies.



Due to their **commercial capabilities**, fleet operators have the opportunity to capture a share of the profit pool by partnering with OEMs and tech companies, to build connected trucks tailored to their transportation needs. This could lead to greater **market fragmentation** as the supply chain activity would be integrated within each operator's business.

Driven by software, autonomous trucks require constant connectivity, receiving and communicating high volumes of information - four terabytes of data per hour. As truck manufacturers don't possess these **software and innovation capabilities**, technological companies have the opportunity to move **upstream into the logistics market**, providing **freight matching solutions** to manage these large streams of data.

There have been increasing **strategic partnerships** targeting Level-4 autonomous trucks between **OEMs** and **technological companies**, merging the knowledge and experience in truck manufacturing with advanced digital technology. By joining forces, these companies are sharing R&D, being able to leverage big data of state-of-art autonomous trucks to identify and solve challenging situations and validate the technology. A prime example would be the partnership between **Waymo**, an autonomous vehicle firm owned by Alphabet, and **Daimler Trucks**, which have driven more than 20 billion miles on public roads across the U.S. in simulations.

Source: PwC - The Era of Digitized Trucking, 2018;

Automated freight matching platforms are improving supply chain efficiency, and could replace traditional brokers

New Business Models

2.3

The current manual freight demand and supply matching process will be disrupted by **freight matching digital platforms**. These platforms will leverage data analytics capabilities to match the supplier with the customer and manage their transactions, making the supply chain more efficient. By automating this process, **delivery time could fall** by 40% and **inventory turnover would decrease**.

Telematics technology enables a truck trailer to detect its freight capacity and destination, sharing this information to the platform.

- Cargo equipped with smart communication chips can directly **signal autonomous trucks**, sharing important information such as weight or delivery address. Algorithms combine this data with the truck's cargo availability, location and direction, and decide the best fit.

- Trucks heading in a similar direction to the product's address would be signalled and **directed to the warehouse** to collect and transport it.
- By using **smart contracts**, an agreement would take place between the cargo owner and the end customer, which should be better off as freight prices will be pressured by the platform's **transparency**.

Logistic operators, such as third party logistics and freight forwarders, face the risk of being **pushed out of the market**, as automated freight matching platforms will replace the traditional inefficient brokerage role, possibly reaping their margins (15 to 20%).

Source: PwC - The Era of Digitized Trucking, 2018; Roland Berger: Shifting up a gear, 2018;

Autonomous trucks will operate in a controlled environment with the development of new business models

New Business Models

2.3

Platoon Service Provider

Matching

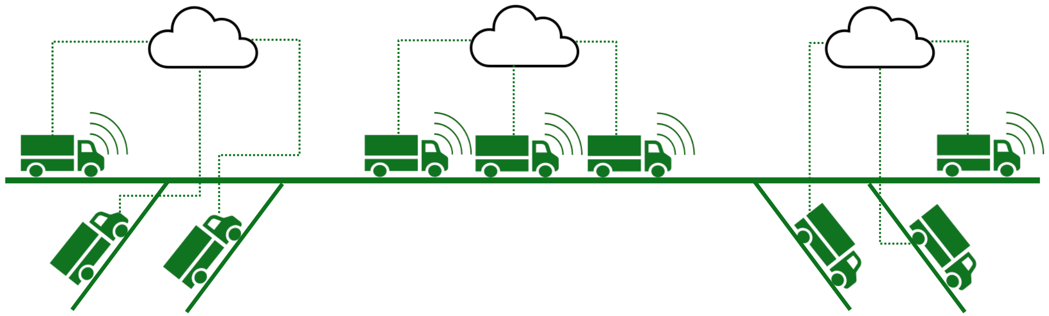
The service provider selects and matches the trucks (within the same fleet or not) based on route timetables.

Coupling

Formation of truck platoons during the shared part of the trip, which is supervised and coordinated by the service provider.

Uncoupling

Trucks detach from the platoon and conclude their journey individually.



Transfer Stations

In a scenario where driverless trucks travel in autonomous highway segments, first and last mile delivery will still require a truck driver. Therefore, **trailers would need to shift** between the two different trucks. This change would occur in dedicated **transfer areas, situated close to the highway**, to guarantee its direct access.

First Mile → **Hub-to-Hub** → **Last Mile**

Source: Roland Berger: Trends in Truck Trailer, 2018;

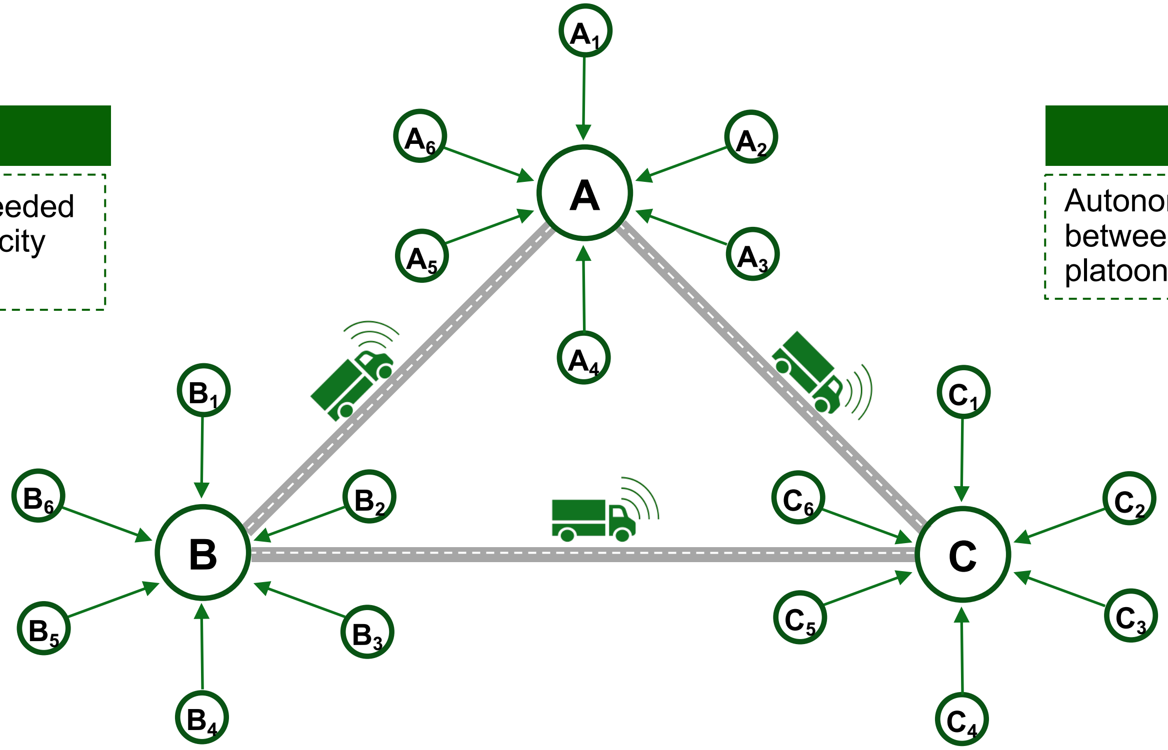
All in all, autonomy won't replace the whole transportation task, but hub-to-hub routes could be dominated by driverless trucks

Implications for the freight distribution network

2.3

First & Last Mile

A local truck driver will still be needed to transport freight between the city and the hub.



Hub-to-Hub

Autonomous highway segment between hubs where trucks will form platoons.

Large distribution hubs will emerge

Vast warehouses in suburban areas are required to face urban logistics' limitations. They will be prepared to handle significant freight volumes with the support of warehouse automation, freight matching and data-driven truck routing. To ensure smooth operations with trucks, these hubs should be equipped with compatible loading docks and automated loading and unloading systems. Due to higher delivery speed and flow of information, inventory turnover will fall together with storage costs.

Source: PwC - The Era of Digitized Trucking, 2018; Roland Berger: Shifting up a gear, 2018;

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Chapter 2 – Key takeaways

2	Autonomous Trucks	**The Impact of Autonomous Driving in the Trucking Ecosystem**
2.1.	Today's Ecosystem	Trucks are dominant mode of freight transportation both by value and weight. The hub-to-hub segment employs 1.8 million truck drivers and operates almost 4 million trucks. The industry is extremely fragmented, with 91% of all operators have fewer than 10 trucks. Other digital technologies are unlocking the full value of autonomous driving.
2.2.	Full Potential Value Creation	Truck Utilization could increase from 33% to 83%. The required fleet to transport the same freight volume would decrease by 2.5x. Autonomous trucks could save $87.57 billion in driver wages per year. The cost per mile could decrease by 53%.
2.3.	The Way Forward	Platooning could be a bridging technology in the adoption of autonomous trucks. The driver shortage could trigger the adoption of autonomous truck technology, but driver resistance is expected. For an owner-operator, an autonomous trucks can pay itself 4x faster than a conventional truck, and the total cost of ownership could decrease by 47%. Greater industry concentration is expected due to economies of scale. The value of a truck will shift from hardware to software. Autonomous trucks will create new business models, such as platoon service providers, transfer stations and freight matching digital platforms. Large distribution hubs will emerge with autonomous highways segments