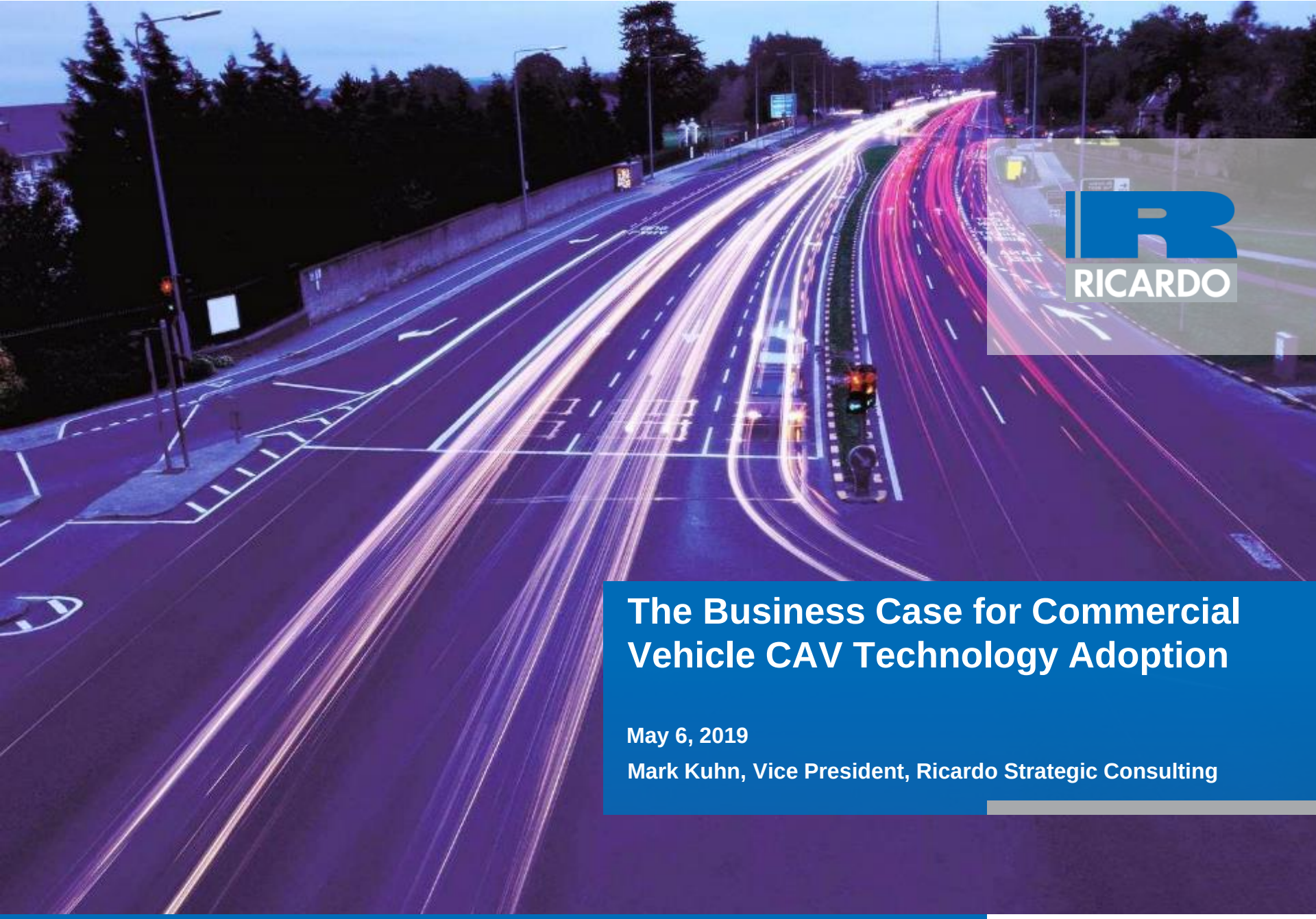


The Business Case for Commercial Vehicle CAV Technology Adoption

May 6, 2019

Mark Kuhn, Vice President, Ricardo Strategic Consulting

Contents

- Introduction to Ricardo Strategic Consulting
- Commercial Vehicle Technology – brief overview
- Cost / Benefit analysis
- Conclusions

Ricardo has a deep history in the vehicle sector and is well positioned to provide value with a global footprint

1915

Providing technology, product innovation, engineering solutions and strategic consulting to the world's automotive industries since 1915.

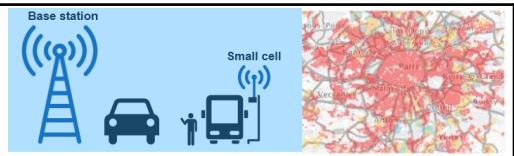
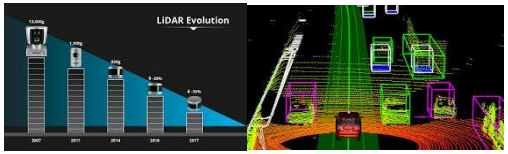
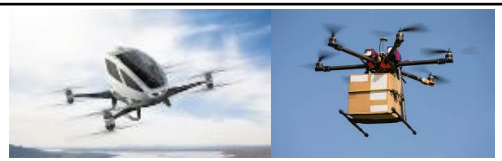
- A global, multi-industry, multi-discipline consultancy and niche manufacture of high-performance products
- The objective throughout our history has been to maximize efficiency and eliminate waste in everything we do

Today

Ricardo is a global strategic, technical and environmental consultancy and specialist niche manufacturer of high performance products. We also provide independent assurance services in the rail sector.

RSC is providing strategic insight, technology roadmaps and assessing market opportunities for clients in advanced mobility

Example Activity Areas

Connectivity Vehicles and the Internet of Things		• The connectivity revolution • Offboard vehicle technology roadmap • OTA / Telematics revenue streams • Role of 5G and DSRC
Dominance of ADAS Sensor systems Complexity and cost management		• Production ADAS benchmarking • Technology and cost roadmaps • Evolution of electronic architecture • Future software and hardware value
Cybersecurity		• Cybersecurity and the Vehicle • Knowledge development courses • Automotive resilience strategies • Customized cybersecurity support
Rise of Mobility as a Service		• Use cases for urban mobility vehicles • Market sizing & deployment rates • Economic impact for consumers • Impacts to traditional value chain
Pervasiveness of Personal Mobility Vehicles Connected, electric 2 and 3 wheelers		• Growth in use cases for 2Ws • Two wheeler market growth • Connectivity as an enabler for growth • City mobility and 2W / 3W for hire
Arrival of passenger, goods and surveillance drones		• Piloted drones instead of helicopters • Market opportunity sizing • Component supply chain • Autonomous / unmanned systems

There are a number of drivers for deployment of ADAS and Autonomous technology for trucks

Industry Drivers for ADAS and Autonomous Driving

American Transportation Research Institute states the following top 10 issues for US Truck fleets

1. Electronic Logging Device Mandate
2. Hours-of-Service
3. Cumulative Impacts of Regulations
4. Truck Parking
5. Economy
6. Compliance, Safety, Accountability (CSA)
7. Driver Shortage
8. Driver Retention
9. Infrastructure/Congestion/Funding
10. Driver Distraction

Potential benefits from ADAS and Autonomous technology:

- Improve safety for all road users
- Operational cost benefits through fuel savings
- Improve operational efficiency and reduce costs
- Increase of hours of service by keeping vehicle mobile while driver takes mandated breaks
- Assist with parking
- Meet electronic logging requirements
- Minimize driver distraction
- Reduce stress of driving and improve driver retention

Significant interest from fleets in cost effective ADAS and Autonomous Systems

Vocation-specific benefits of AV technologies is substantial; companies should take a broad view of the opportunities

Autonomous Vehicle Technology Benefits

Benefit	Technology Example	Line haul	Last mile delivery	Short hauls
Safety / Mandate	AEB, ESC, V2V	●	●	●
Collision Avoidance	FCW, RCW	●	◑	◕
Convenience	Parking, HWY lane keeping, traffic jam assist	●	◑	●
Fuel economy, Operational efficiency	Platooning, advanced routing, depot parking, yard shunting	●	○	●
Driverless	Fully autonomous driving	●	○	●

Examples selected for this discussion

Key

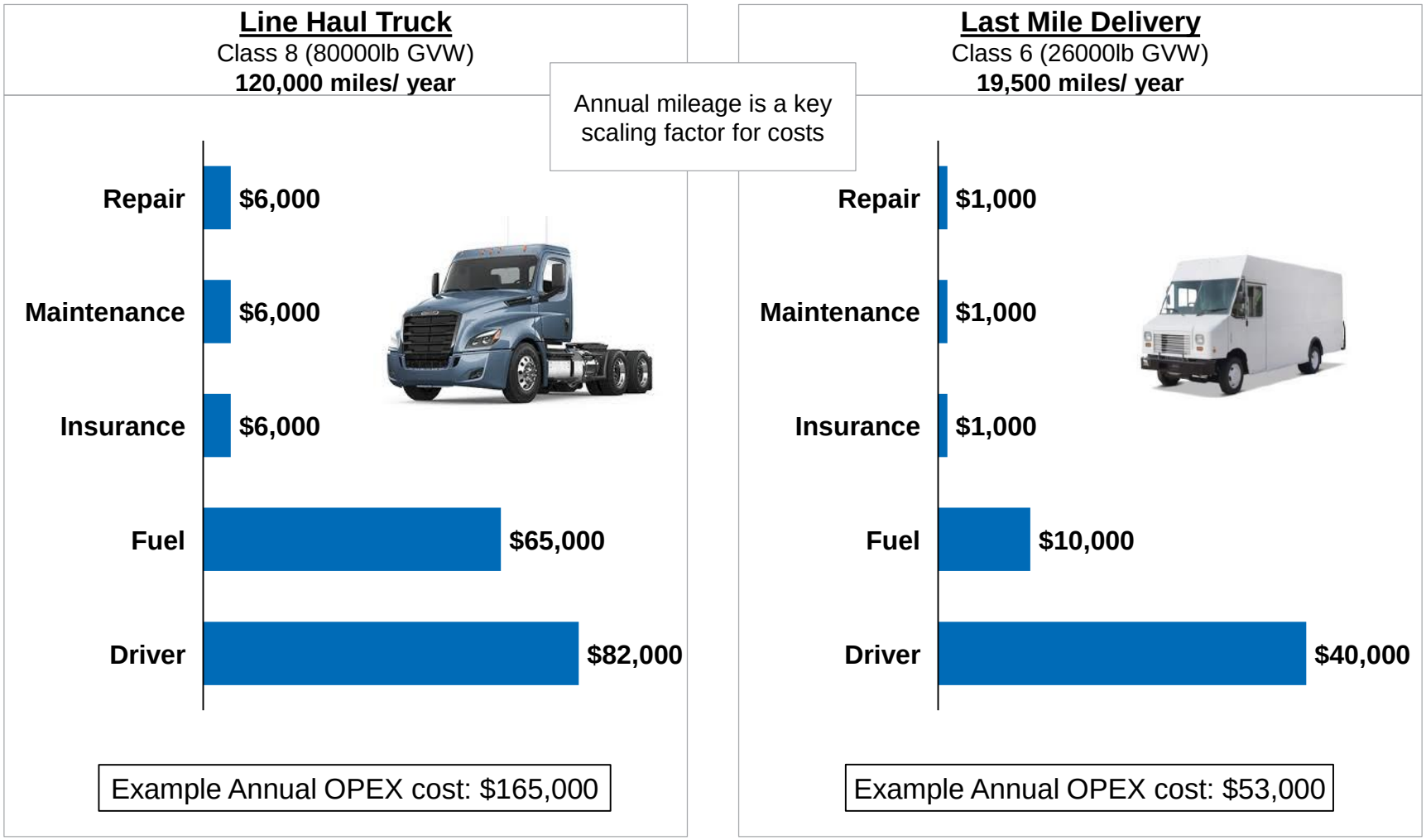
● Substantial benefit

○ Minimal benefit

Short haul is light/medium/heavy duty vehicle with a mix of highway/city driving and a small number of scheduled stops. The vocation is not analyzed in detail here, but included to show there are light/medium/heavy duty vocations which will benefit from autonomous technology whereas last mile delivery may not

Certain vocations such as line haul and some short haul will drive semi and fully autonomous technology development and deployment

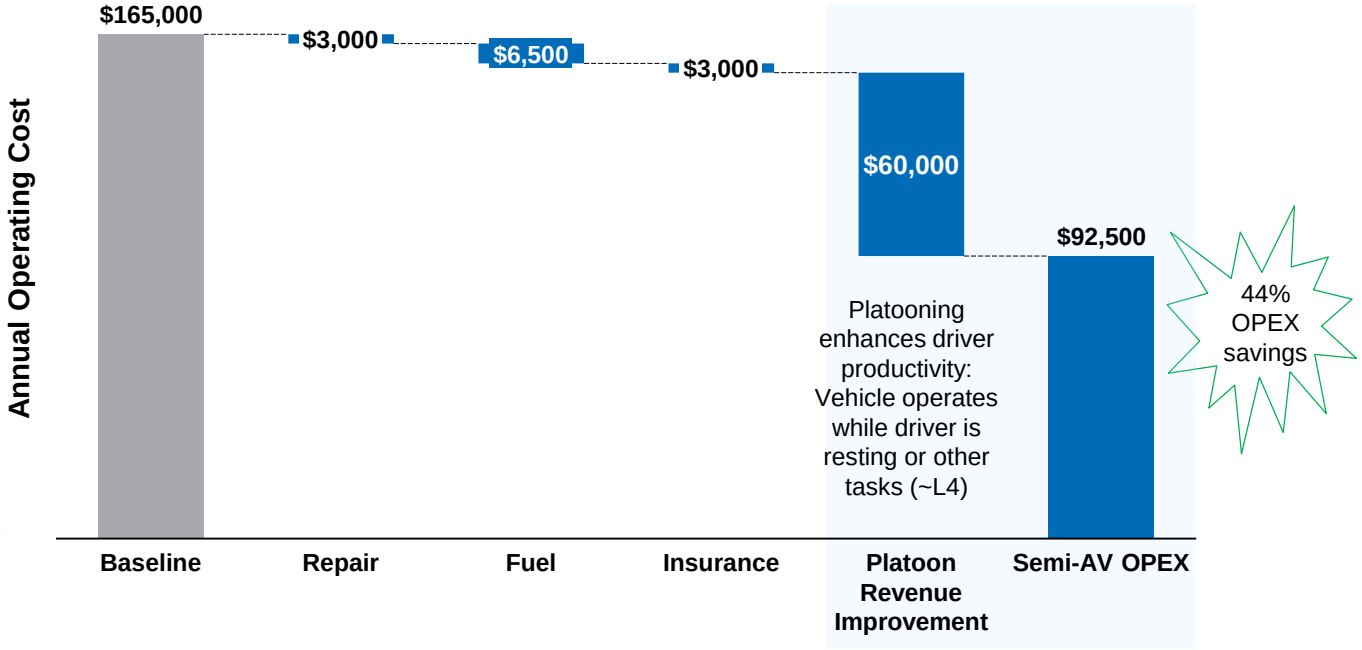
Line haul operations have 6X the OPEX cost of last mile delivery primarily due to higher mileage, except for driver costs (2X)



Source: Ricardo analysis of average cost within US truck industry scaled by truck mileage where appropriate

Semi-autonomous line haul trucks receive significant OPEX benefit from platooning: fuel economy and driver productivity

Example Economic Opportunity for Line Haul Trucks

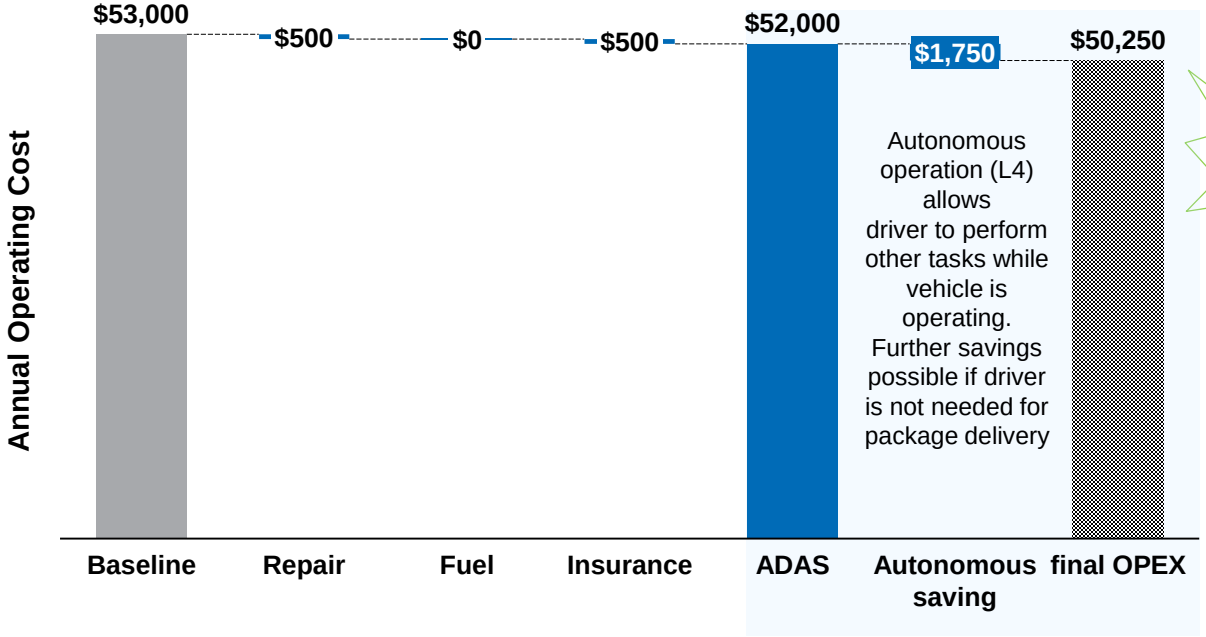


US freight volume expected to grow **2012: 13.2 B Tons** ***+43%*** **2040: 18.8 B Tons**

Assumptions:
- Based on Line Haul scenario.
- **RESULTS WILL VARY WITH ASSUMPTIONS ON VEHICLE OPERATION**
- **SOURCE: DOT 'BEYOND TRAFFIC' REPORT**

Last mile package delivery scenario shows limited financial benefit for autonomous driving unless driver costs reduce

Example Economic Opportunity for Last Mile Delivery



Last mile delivery market is growing at 7 to 10% rate in developing countries

Assumptions:
Based on last mile, package delivery
RESULTS WILL VARY WITH ASSUMPTIONS ON VEHICLE OPERATION

A scenario of potential benefits for ADAS and Autonomous Technology can be used to assess economics of adoption

Scenario to assess economic benefit of ADAS and Autonomy

Operating Cost	Line Haul	Last Mile Delivery
Repair	• ADAS can prevent accidental damage • Fully autonomous should have no accidents	• ADAS can prevent accidental damage • Fully autonomous should have no accidents
Maintenance	• Assumed not impacted by ADAS or Autonomy • Would benefit from connected services	• Assumed not impacted by ADAS or Autonomy • Would benefit from connected services
Insurance	• Reduction due to lower accidental damage • Anti-theft is additional benefit from connected services	• Reduction due to lower accidental damage • Anti-theft is additional benefit from connected services
Fuel	• Fuel efficiency benefits from platooning	• Limited fuel economy benefit except from improved low speed crawl • Connected services could improve efficiency
Driver	• Operational efficiency benefit if vehicle moves while driver rests	• Last mile delivery may always need a driver to deliver the package from the vehicle. Hence limited benefit from full automotive without additional handling infrastructure

Scenario only includes ADAS and Autonomous Technology.

Operational benefits from connected services were not included; and are additive to the above benefits

Last mile drone delivery is growing, and further demonstrates benefits of connectivity opportunities

Example: Drone Grocery Last Mile Delivery

Kroger: objectives of unmanned pilot delivery in Scottsdale, Arizona

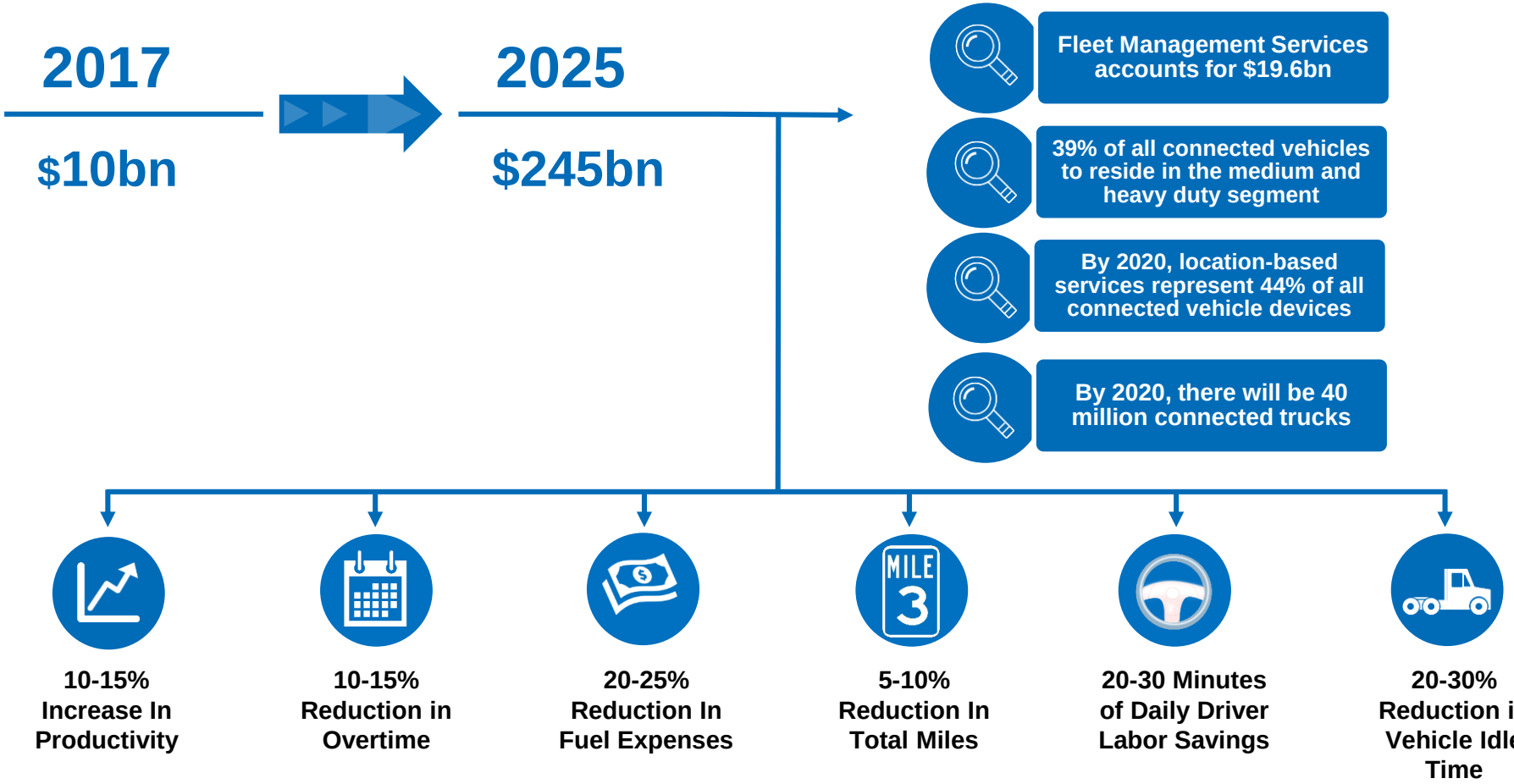
- Place an order on mobile app or website; order same-day or next-day
- 7 days/week $5.95 flat fee; no minimum order
- “redefine the grocery experience by creating an ecosystem that offers our customers anything, anytime and anywhere“ – Kroger
- AZ program will end in May after ~2000 grocery deliveries; now expanding to Houston
  - customers who participated in the Scottsdale pilot will switch over to an existing grocery-delivery service provided by Kroger.

4 percent of Americans shop for groceries online on a weekly basis; Gallup researchers concluded that this highlights the industry’s potential for large-scale change.

Reference: Forbes, Dec. 19, 2018 https://www.forbes.com/sites/lanabandoim/2018/12/19/kroger-is-using-unmanned-autonomous-vehicles-to-deliver-groceries-in-arizona/#4cfb22102f57
Arizona Republic, March 17, 2019

Connected truck market currently valued at $10bn; expected to grow to $245bn by 2025

Connected Services Market Value (V2V, V2I)



Annual OPEX savings: $6k to $9k (MD Delivery truck) $20k to $30k (Long haul truck)

Source: Frost and Sullivan's Global Connected Truck Study

Value of connected services needs to be understood for targeted truck vocations to identify the most relevant features

Potential Benefits for Technology Providers / OEMs

Potential Benefits for End-users (fleets)

	Cost Reduction	Time Savings	Safety & Security	Convenience	Other
Revenue via direct monetization •*Upfront payment* •*Subscription* •*Usage based*	Advanced scheduling *(25% of EU truck trips are empty vehicles)* (5)	Advanced routing *(Avoid road work, congestion, etc.)* (9)	Anti-theft *(Vehicle & Cargo monitoring)* (6) (8)	Over-the-air software updates	Road law monitoring and enforcement
	On-demand delivery services	Rapid deployment (2)	Driver condition monitoring (6) (10)	Telematics diagnostics	
	Fleet management solutions	Traffic Information (9)	Breakdown / Emergency call service (6)	Automatic completion of mandated forms (1)	
	Predictive maintenance and scheduling	Parking spot finder (4)	Improved road maintenance (9)	Automation of fleet specific requirements (delivery notification) (8)	
	Driving style monitoring and recommendations		Geo-fencing of operations in sensitive areas (6)	Music/video streaming	
	Usage based insurance, tolls and taxes		Inclement weather warning & speed management	Wifi hotspot	
	Vehicle Uptime Improvement		Road hazards	Concierge services	
	Enabling truck platooning			E-payments	
	Intelligent Transportation *(Eco-approach/departure)*				
Cost Reduction					Warranty cost reduction
					Data driven R&D optimization
					OTA updates (reduced dealership costs)

American Transportation Research Institute top 10 issues for US Truck fleets (Number reference in table above correspond to numbers below)

1. Electronic Logging Device Mandate
2. Hours-of-Service
3. Cumulative Impacts of Regulations
4. Truck Parking
5. Economy
6. Compliance, Safety, Accountability (CSA)
7. Driver Shortage
8. Driver Retention
9. Infrastructure/Congestion/Funding
10. Driver Distraction

Connected Vehicles can generate up to 25 Gbytes of data per hour !
Key question: where is the real value in all the data and how do we effectively extract it?

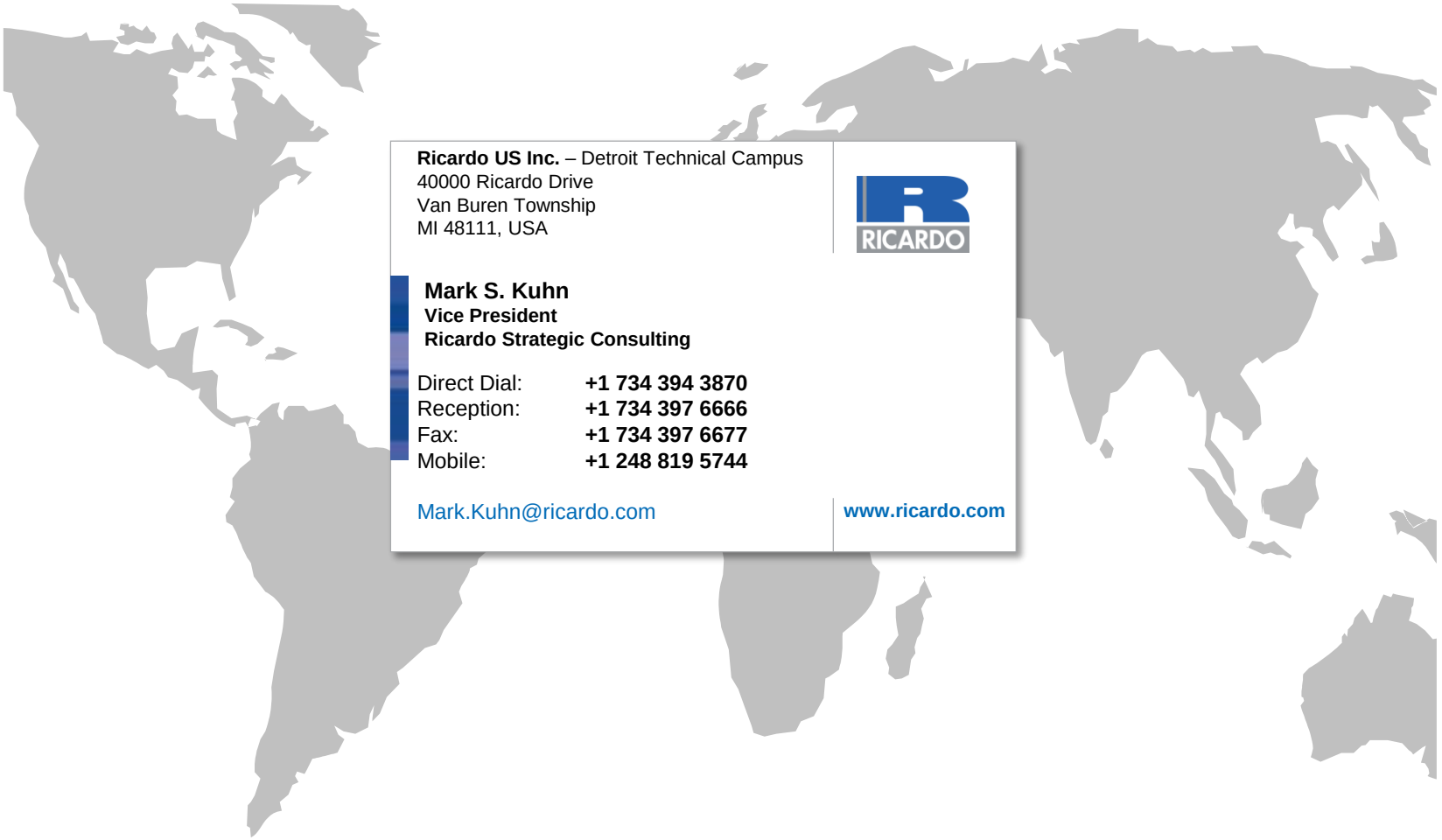
Source: Ricardo analysis

Conclusions

Technology	Ricardo View
Connectivity	• Will have **significant impact** on commercial vehicle operations **in next few years** • Could help **redefine business models** in select vocations • Will likely **enable other ADAS and Autonomous driving** features
ADAS (SAE level 1 and 2)	• May not have strongest business case, but **could reduce repairs/insurance and help with driver attraction/retention**. • Certain ADAS features likely to be **mandated** for safety • May need to be offered to be competitive in market
Semi-Autonomous (SAE level 3 and 4)	• **Strong business case for certain vocations**, will be adopted in these vocations as soon as available **(e.g.: line haul).** • Some vocations do NOT show as attractive a business case for semi-autonomous (e.g. last mile) • **Platooning likely to enter market in near future** driven by European and US interests
Fully-Autonomous (SAE Level 5)	• Excludes level 4 highway pilot / platooning / traffic jam assist where full autonomy is possible in certain situations • **Significant cost-benefit advantage in certain vocations will continue to drive development** • **A fully autonomous, all time vehicle appears to be several years away**

Significant opportunity for connectivity across all vocations, and quick deployment of semi-autonomous in select vocations

Thank You



Ricardo US Inc. – Detroit Technical Campus
40000 Ricardo Drive
Van Buren Township
MI 48111, USA

Mark S. Kuhn
Vice President
Ricardo Strategic Consulting

Direct Dial: **+1 734 394 3870**
Reception: **+1 734 397 6666**
Fax: **+1 734 397 6677**
Mobile: **+1 248 819 5744**

Mark.Kuhn@ricardo.com

www.ricardo.com