Short version – To receive the complete study please contact our US marketing department at linda.saliba@rolandberger.com

Automated Trucks

The next big disruptor in the automotive industry?

Roland Berger study

Chicago / Munich – April 2016

THE BIG 3

Disruption potential

Automated trucks address several challenges that the trucking industry is facing simultaneously: hours-of-service, safety, driver shortage and fuel costs

TCO benefit

In early stages, fast payback of technology investment can only be reached in few applications with high share of truck platooning – significant cost savings expected only long term with driverless trucks

Safety as true driver

As pull from fleet operators will be limited given the slow payback, safety regulation will become a major driver in the adoption of automated trucks

Source: Roland Berger

Hours-of-service, safety, driver shortage and fuel costs are top issues of the trucking industry

Top issues of the trucking industry

HOURS OF SERVICE
DRIVER SHORTAGE
FUEL COST
CONGESTION
DRIVER RETENTION
PARKING
DRIVER DISTRACTION
ECONOMY
SAFETY
DRIVER WELLNESS

Source: ATRI; Roland Berger

Most of the top trucking industry issues can be addressed by automated trucks – Benefits expected also for wider society

Top industry issues addressed by automated trucks

Fleet owner impact

Hours-of-service
Optimized resting times for driver of trailing vehicle

Safety
90% of truck accidents caused by human error

Driver distraction
Autonomous technology compensates for driver's lack of attention

Fuel costs
Mileage improvements through better aerodynamics

Driver shortage
Changed driver role might attract younger drivers

Driver retention
Reduced driving stress and fewer monotonous time periods

Congestion
Smaller distance between trucks reduces road area used

Driver wellness
More rested drivers and reduced sleepiness

Society impact

- Emission reduction
- Accident mitigation
- Safer roads
- Congestion reduction

Source: ATRI, Roland Berger

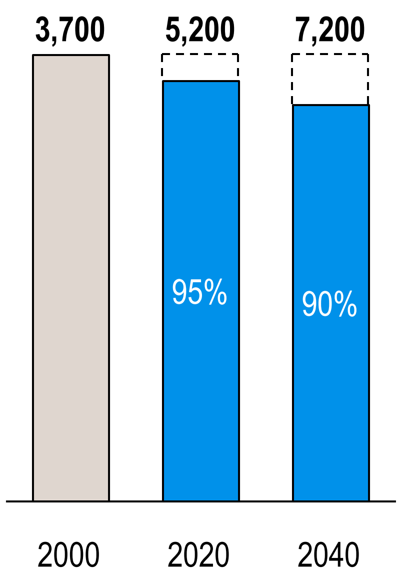
Automated trucks have the potential to bring a disruptive change to the trucking industry

Automated trucks – Disruption potential

Indicative

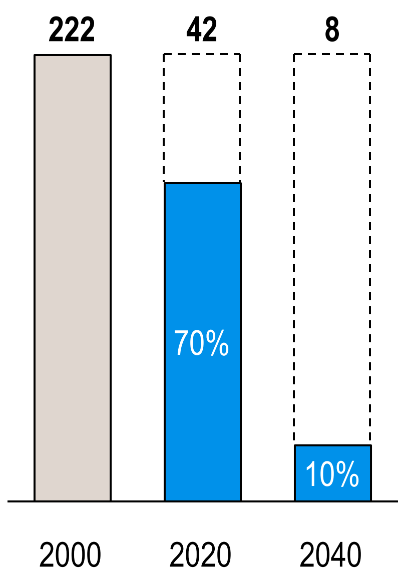
Fuel consumption

Energy consumption heavy duty trucks [tn Btu]



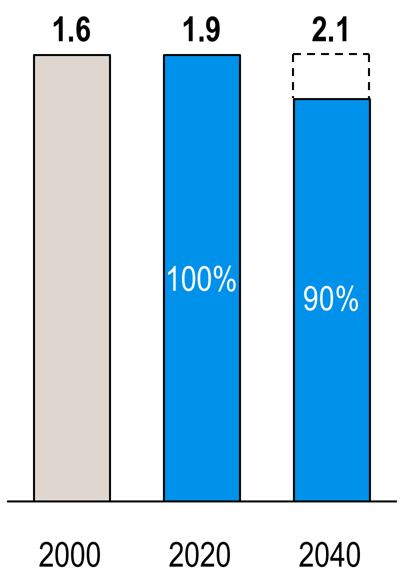
Safety

Trucks involved in crashes [per 100 m vehicle-miles]



Driver demand

Number of heavy duty truck drivers [m]



Others

> Reduction of traffic jams
> Higher driver retention
> Improved truck utilization
> Lower transport cost
> Emergence of new business models

Base year 2000 | Projected development w/o automated trucks | Potential development with automated trucks

Source: EIA; NHTSA; BLS; Roland Berger

Benefits of automated trucks are twofold: safer and more comfortable vehicle operation and fuel savings from platooning

Benefits from automated trucks

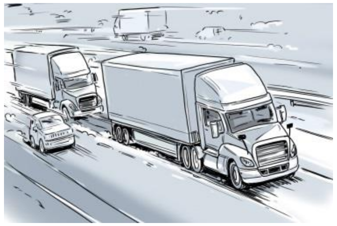
Automated driving

Increased driver comfort and safety through fully automated vehicle operation

Benefits
> Optimized driver rest periods
> Fuel efficiency gains from predictive driving
> Eliminating human error
> Better vehicle utilization
> Eventually driverless vehicle

Cooperative automated driving

Improved aerodynamics and fuel consumption through reduced inter-vehicle spacing



Benefits
> Additional fuel efficiency gains

Self-driving trucks

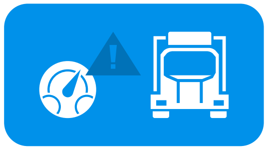
Source: Roland Berger

The technological development towards fully automated trucks takes place in stages – Driver engagement changes with stages

Technological roadmap (SAE stage definition)

Stage 0
No Automation

Driver is fully engaged all the time, warning signals might be displayed



Stage 1
Driver Assistance

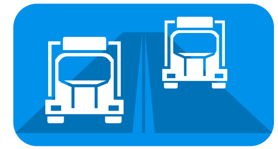
Automation of individual function, **driver fully engaged** – Driver may be "feet off" (when using ACC) or "hands off" (when using Lane Keep Assist)

Stage 2
Partial Automation

Automation of multiple functions, **driver fully engaged** – Driver may be both "feet-off" and "hands off", but eyes must stay on the road

Stage 3
Conditional Automation

Automation of multiple functions, **driver responds to a request** to intervene – Driver may be "feet-off", "hands off" and "eyes off", but must be able to resume control quickly



Stage 4
High Automation

Automated in certain conditions, **driver not expected to monitor road – Driver has no** responsibility during automated mode

Stage 5
Full Automation

Situation independent automated driving – Driver has no responsibility during driving

Source: SAE; Roland Berger

Roland Berger

Each stage of automated trucks requires increasingly complex features that transfer more control from the driver to the truck

Required features by stage of automation

Stage 0 – No Automation

> Blind spot detection/ right turn assistant
> Collision warn system
> Lane departure warning system
> Driver monitoring system
> Traffic sign recognition

Stage 1 – Driver Assistance

> Emergency braking system
> Adaptive cruise control or
> Lane keep assist
> Driver-assisted truck platoon (DATP)

Stage 2 – Partial Automation

> Traffic jam/ construction site assistant
> Highway assist
> Predictive powertrain control
> Lane change assist incl. right-turning
> Intelligent parking assist system

Stage 3 – Conditional Automation

> Platooning
> Real time communication between trucks via V2V/DSRC
> Highway pilot – driver "alert"

Stage 4 – High Automation

> Highway pilot – no driver responsibility

Stage 5 – Full Automation

> Truck pilot

Today (Stage 0 – Stage 1) | Pending (Stage 2) | Future (Stage 3 – Stage 5)

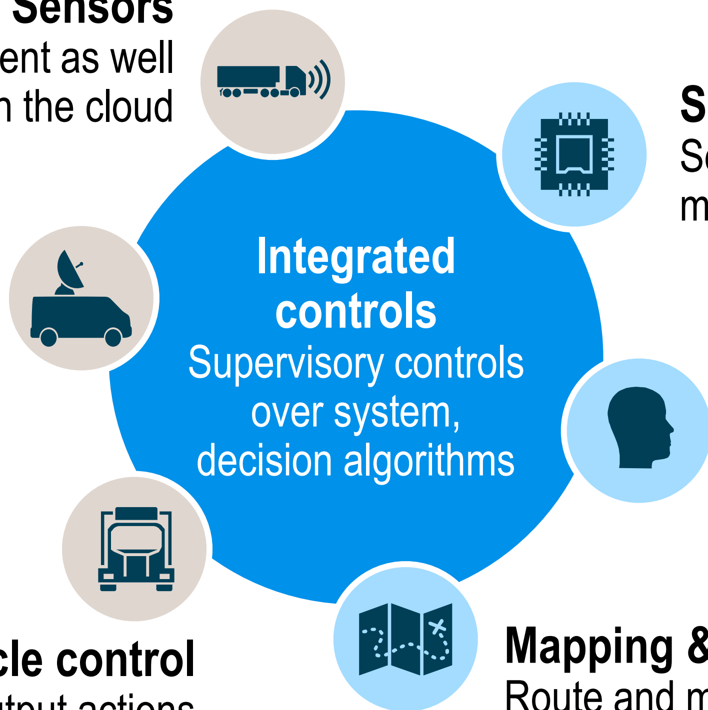
Source: SAE, Roland Berger

Autonomous trucks are enabled by an interplay of technology areas including hardware, software and integrated controls

Key technology requirements automated trucks

Sensors
Input about the environment as well as communication with the cloud

V2X connectivity
Communication with other trucks (e.g. for platooning) and with infrastructure (e.g. buildings & roads)



Vehicle control
Vehicle actuation and output actions

Spatial imaging
Sensor data fusion for environmental model & object recognition

Human-Machine-Interface (HMI)
New driver interaction patterns

Mapping & path planning/control
Route and motion planning on map data and motion

Hardware focus | Software focus

Source: Roland Berger

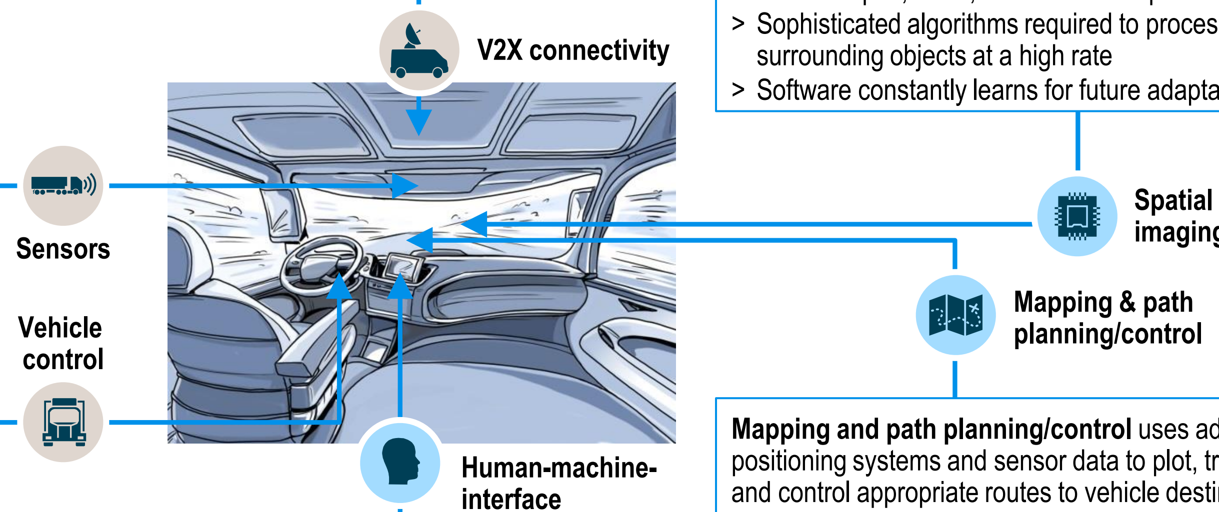
A variety of sensors, connectivity and vehicle control systems are used in automated trucks along with HMI and software modules

Technologies used in automated trucks

Sensors monitor the surroundings of the vehicle
> Radar sensors monitor traffic in front (Stage 1) and to the sides of the truck (Stage 2)
> Front stereo camera adds redundancy and monitors traffic in front (Stage 3)
> Lidar creates high resolution 3D environmental data (Stage 3)
> Internal camera monitors driver to ensure that he can take back control if needed (Stage 3)

Vehicle connectivity (V2V/V2I) is not required for automated vehicles in Stage 1 and 2, but platooning depends on V2V communication between paired trucks

Spatial imaging is done by aggregating the inputs from all sensors to develop 3D maps
> Profile mapping of surroundings includes data about shapes, sizes, distances and speeds
> Sophisticated algorithms required to process surrounding objects at a high rate
> Software constantly learns for future adaptation



Vehicle control allows steering of the vehicle
> Automated steering for lateral control of the vehicle (Stage 2)
> Automated manual transmission (Stage 2) already on significant share of US trucks (~40%)
> Central ECU processes all sensor data (Stage 3)

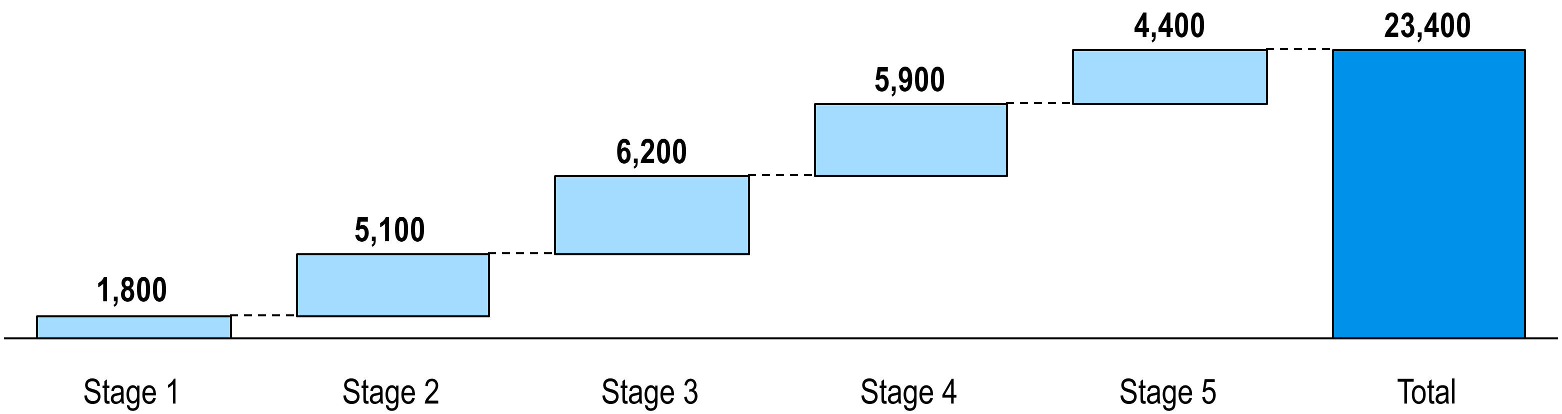
HMI communicates vehicle information to the driver
> Informs the driver about the automated mechanical actions of the vehicle
> Warns or instigates action from driver
> Displays 3D map that the vehicle uses for its operations to help with driver's visualization

Mapping and path planning/control uses advanced positioning systems and sensor data to plot, track and control appropriate routes to vehicle destination
> System processes GPS data along with real time information received from imaging and mapping sensors like cameras and radar
> Complex software required to determine positions of surrounding vehicles with precision and account for other variables like traffic, road conditions, accidents etc.

Source: Expert interviews; Roland Berger

Incremental costs of automated driving increase from Stage 1 to 5 – Total incremental cost of stage 5 truck over 20 k USD

Incremental technologies and vehicle cost per stage [USD per truck]



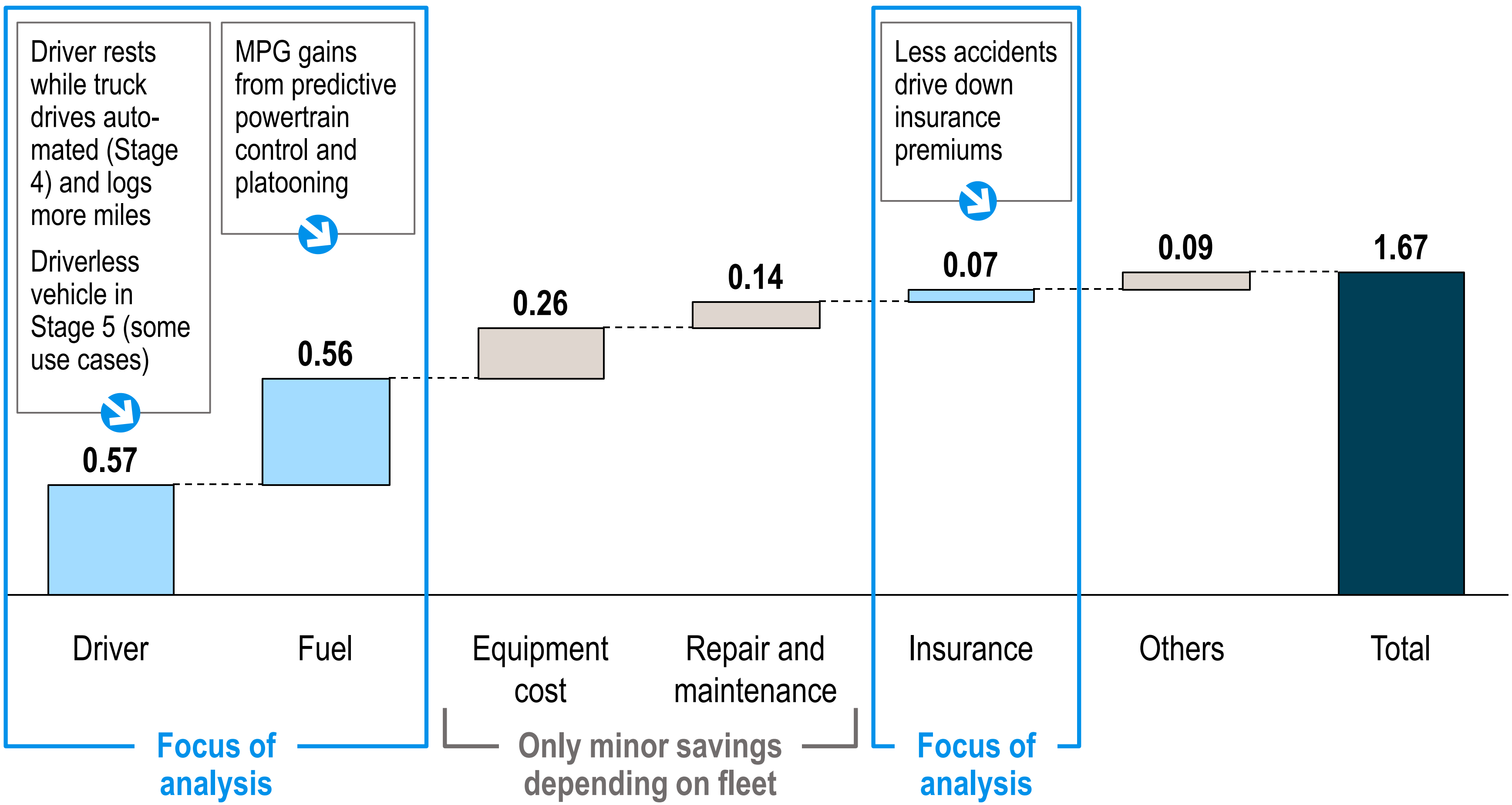
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Incremental software (~85%)	> Processing of sensor data from ACC and/or lane keep assist	> Processing of add. sensor input > Higher level of environmental recognition required	> Higher level of sensing required for conditional replacement of driver's sensory	> Complete automation of sensing process for spec. environment > Calculation of environment map	> Ability to correct for unknown variables in every situation is required
Incremental hardware (~15%)	> Long –range radar > Short-range radar (longitudinal sensing) > Wiring	> Short-range radar (lateral sensing) > Automated steering > Front camera > HMI	> Interior camera > Central ECU > Lidar > Connectivity systems		

( ) Share of cost

Source: Expert interviews; Roland Berger

Driver and fuel are the largest cost items and will be impacted by automated driving – Additional savings on insurance cost possible

Impact of automated driving on operating costs [USD/mile]



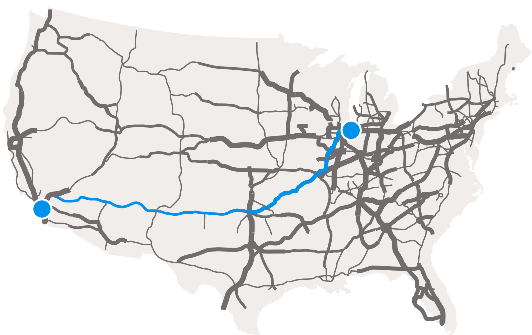
Source: Roland Berger

Roland Berger

We calculated operating cost benefits and investment paybacks for three representative use cases

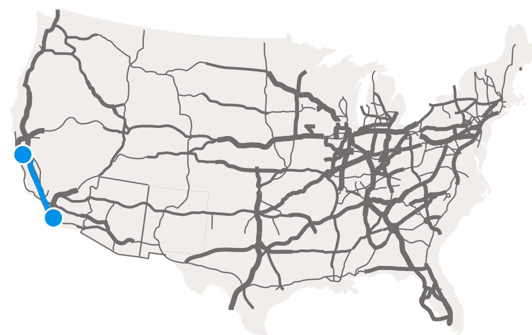
Use cases – Example USA

a Long-haul



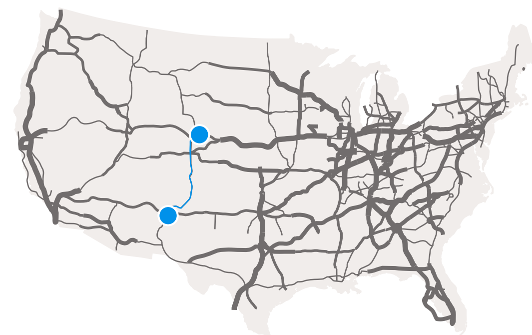
- **Long distance traffic** between warehouse and harbor
- Trip length **2,000 miles**
- **Majority** of trip on **high traffic highways**
- Likelihood to form a **platoon 40%-50%**
- **Driver** not required any more in Stage 5 (fully automated warehouse with automatic loading/unloading)

b Regional – high traffic roads



- **Short distance traffic** between harbor and distribution center
- Trip length **400 miles**
- **Majority** of trip on **high traffic highways**
- Likelihood to form a **platoon 40%-50%**
- **Driver** not required any more in Stage 5 (fully automated warehouse with automatic loading/unloading)

c Regional – low traffic roads



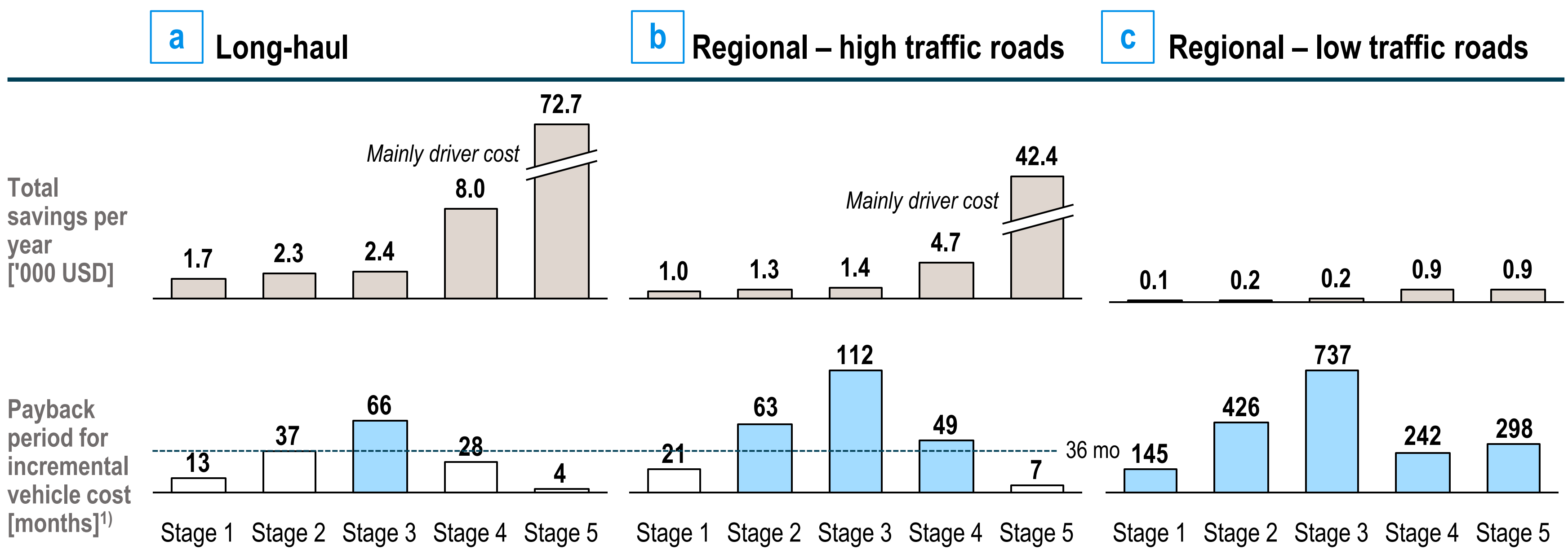
- **Short distance traffic** between regional hub and local warehouse
- Trip length **400 miles**
- **Low share** of trip on **high traffic highways** – Majority on less frequented rural roads
- Likelihood to form a **platoon 10%**
- **Driver** still required in Stage 5, e.g. for loading and unloading

Traffic intensity

Source: Roland Berger

Long-haul case allows payback in 3 years for all stages but stage 3 – Payback times too long for regional transportation

Payback calculation for use cases



Benefits from DATP[2)] quickly offset initial investments in Stages 1 and 2 and driver cost savings allow quick payback in Stages 4 and 5

Benefits from DATP[2)] offset initial investments in Stage 1 and driver cost savings allow payback in Stage 5 – Slow payback in Stages 2-4

Limited benefits lead to long payback times

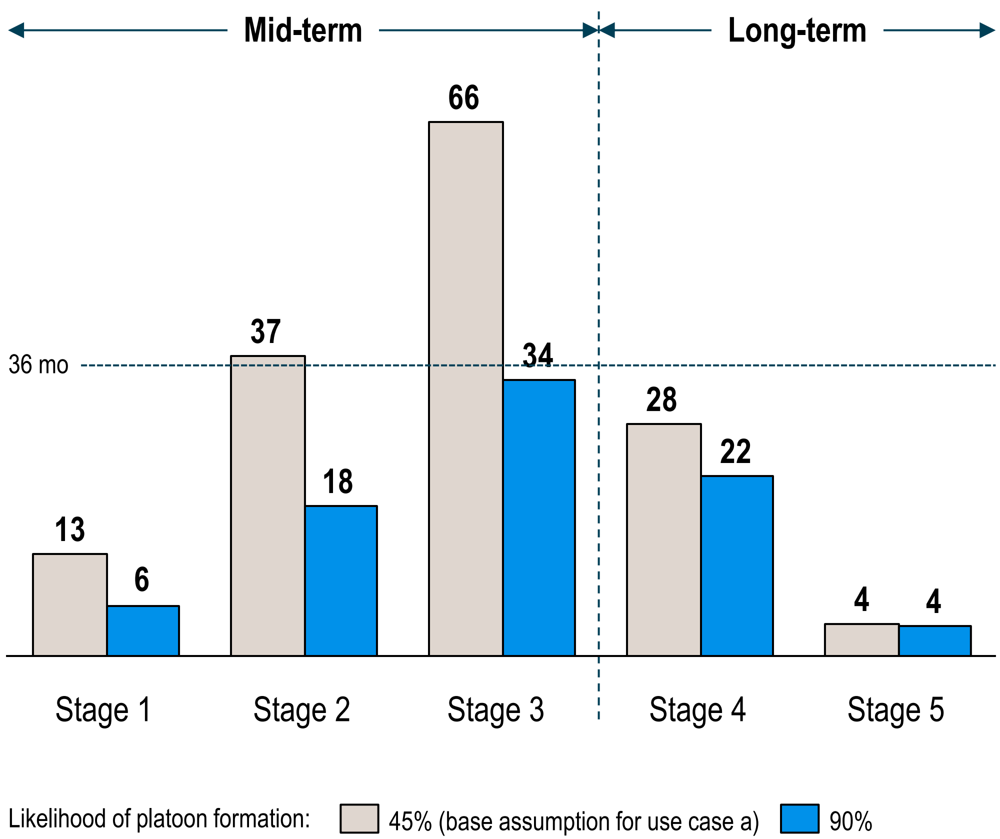
1) Incremental vehicle cost: Stage 1: 1,800 USD, Stage 2: 6,900 USD, Stage 3: 13,100 USD, Stage 4: 19,000 USD, Stage 5: 23,400 USD 2) Driver-assisted truck platoon

Source: Roland Berger

Up to Stage 3, level of platooning will influence adoption of automated trucks, driver cost savings drive adoption in Stage 4

Impact of platooning on payback times [mo]

a Long-haul



Key insights

> Adoption of automated trucks goes through two distinct phases
  - In the mid-term (Stage 1-3), payback periods increase significantly by stage as cost savings remain flat while per vehicle investments grow
  - Level of platooning has significant impact on payback periods up to Stage 3 – Payback within 3 years can only be reached by operating in platoon mode for over 90% of miles travelled
  - In the long-term, payback periods drop with Stage 4 due to additional driver cost savings – fast progression from stage 3 to 4 expected
  - Long-term adoption less impacted by level of platooning

Source: Roland Berger

To realize the potential of automated driving several ecosystem challenges need to be solved

Main requirements for self-driving trucks

1 

Technological requirements

- **Hardware** is largely available with incremental innovation needed
- **Software** & **integration** need advanced development
- **Geo-mapping** needed for highly detailed elevation maps for PPC[1)]

2 

Supply chain development

- **Players** are **forming partnerships** and investing in autonomous trucks technology
- **System integrator required**, **but** still **missing**/too early to define

3 

Legal requirements

- **Legal driving framework** needs to be updated
- **Testing** of automated trucks must be enabled
- **Liability issues** must be clarified

4 

Ethical considerations

- **"Dilemma"** of fair decision vs. rationale decision
- Broad **dialogue among all stakeholders** required
- Needs to serve as **key influence** in legal requirements

5 

Enabling ecosystem

- Availability of required **infrastructure** (e.g., LTE network)
- Truck **driver** acceptance of systems and qualification
- **Cyber security** standards to enable safe truck operation

1) Predictive Powertrain Control

Source: Roland Berger

Four key implications for the trucking industry have been derived

Key implications for stakeholders of trucking industry

		Key insight from analysis	Implication for stakeholders
Safety as real driver behind adoption of automated trucks	1	Business case for fleet operators is positive only for few applications	> Limited pull from fleet operators due to limited commercial benefits > Limited push from OEMs as long as legal issues are not resolved > Tighter safety requirements pushes ADAS into the market and drives adoption of automated trucks
Roles and responsibilities within the value chain change	2	System complexity will significantly increase with higher stages of automation	> Definition of system architectures and responsibility for system integration remains the domain of OEMs across all stages > While OEMs continue to source complete functions from suppliers in Stage 2, a single entity will be required in Stage 3 to handle the higher complexity and interaction between systems (OEM or an ESP) > With Stages 4 and 5 being only software driven, and the need to realize scale effects, it is possible that a large software player gains a large share of the revenue and profit pool
New business models emerge	3	Commercial feasibility of automated platoons requires support functions	> New business models such as Platoon Service Providers or ware-houses with automated loading and unloading functions will emerge
Operator models change	4	Magnitude of cost savings up to Stage 3 depends on ability to form a platoon	> Large fleet operators will gain a competitive advantage over owner drivers as they can more easily form intra fleet platoons and are more likely to platoon with peers than with owner drivers

Source: Roland Berger

Roland Berger

While pull from fleet operators and push from OEMs will remain limited, safety regulation will drive adoption of automated trucks

Technology push and pull from different stakeholders

Fleet operators

Limited pull from fleet operators due to limited commercial benefits

Regulation

Tighter **safety requirements** pushes ADAS into the market and drives adoption of automated trucks

Automated truck

OEM

Limited push from OEMs as long as legal and cyber security issues are not resolved

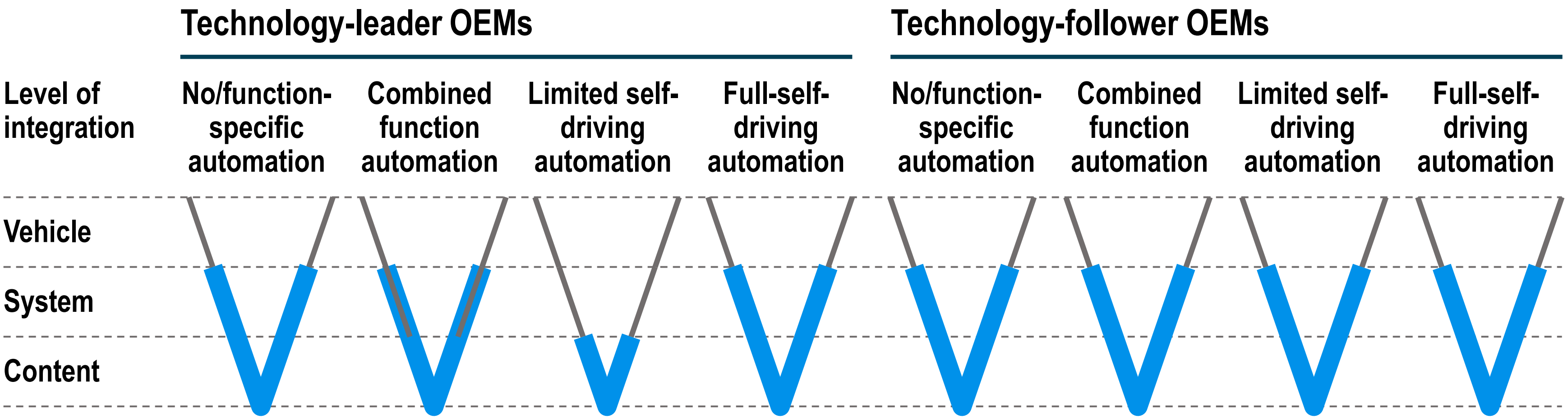
Extend of push / pull

Source: Roland Berger

Roland Berger

Roles and responsibilities within the value chain will change with different stages of automation

Role sharing between OEMs and suppliers



Role of OEMs

Technology-leader OEMs:

- Complete **system understanding**
- Integrate **fail-operational vehicle safety** concept
- Drive **ADAS acceptance** (regulation/customer acceptance)

Technology-follower OEMs:

- Responsible for **vehicle-level integration**

Role of suppliers

Technology-leader OEMs:

- **Holistic ADAS understanding** from components (sensors and algorithms) to complete systems
- **Infrastructure co-development** (V2V, V2I)

Technology-follower OEMs:

- **Development lead** for affordable and secure ADAS solution
- **Complete system competency** including sensors and software capabilities

OEM | Supplier

Source: Roland Berger

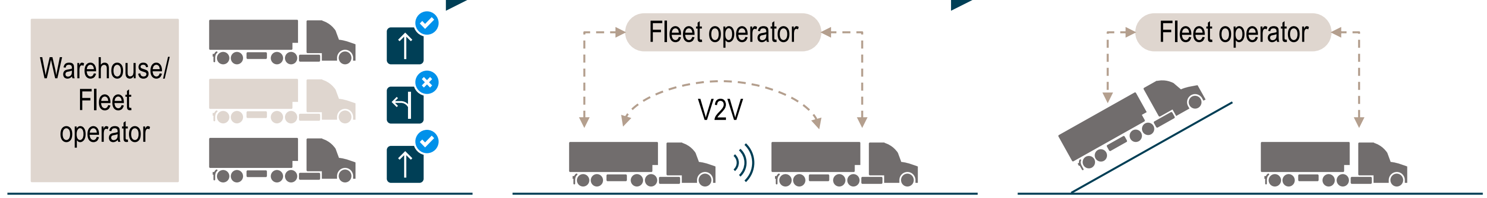
Roland Berger

Platoon Service Providers are expected to emerge that orchestrate platoon formation across fleets

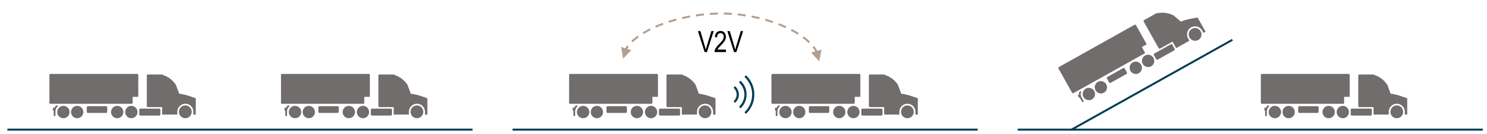
Business model change: Platoon formation options

Increasing complexity / Possible implementation path

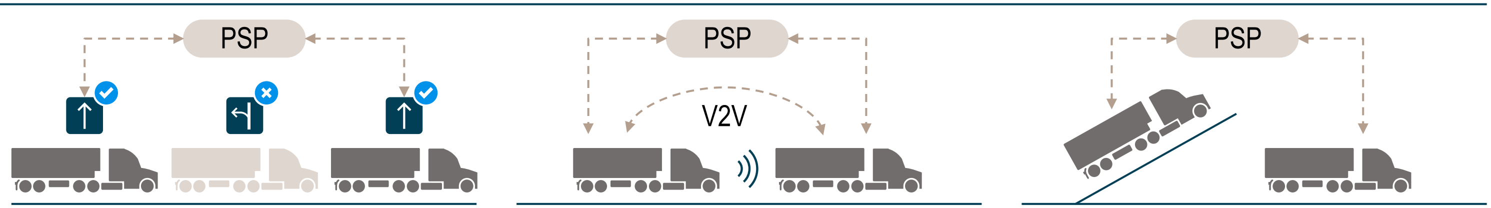
	Matching	Pairing	Disengagement
Scheduled platoons (inter fleet)	> Fleet operator selects trucks to form a platoon based on trip schedules	> Trucks form platoon for the common part of their trip, monitored by fleet operator	> Trucks drive independently to final destination



	Matching	Pairing	Disengagement
On-the-fly platooning (intra fleet)	> Trucks form ad-hoc platoons on highly frequented corridors – no matching of trip plans	> Trucks form platoon for the common part of their trip	> Trucks drive independently to final destination



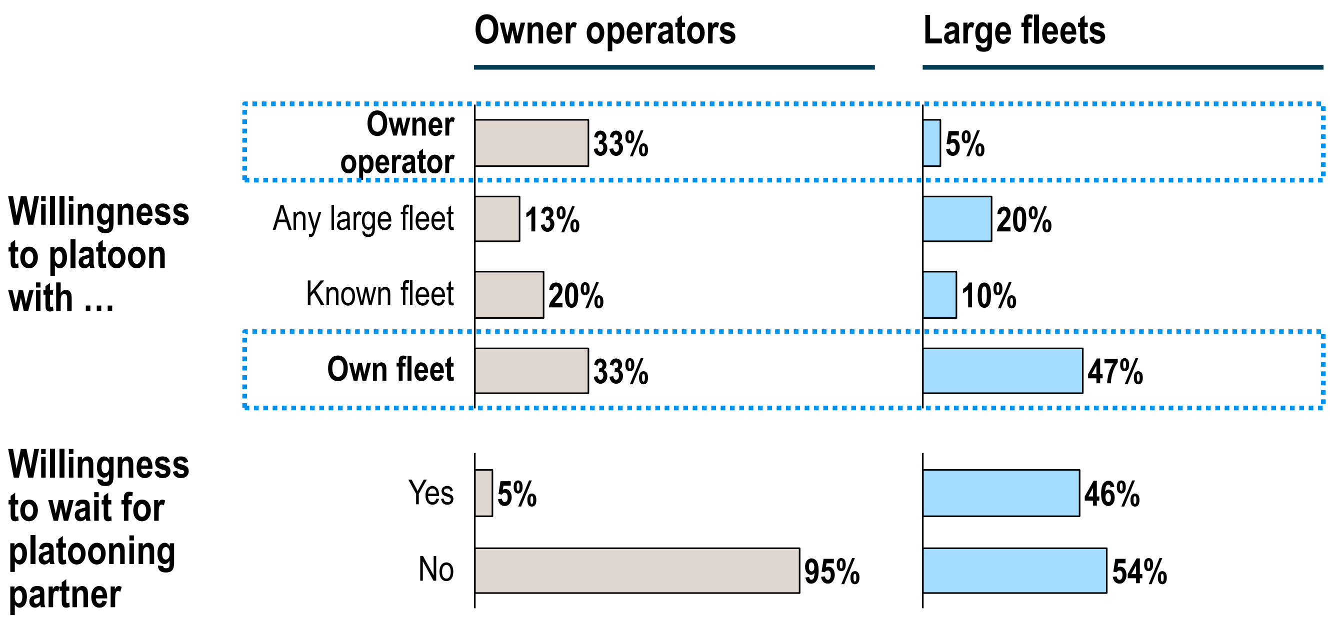
	Matching	Pairing	Disengagement
Orchestrated platooning (intra fleet)	> Platoon Service provider (PSP) matches trip schedules	> Trucks form platoon, coordinated and monitored by PSP (e.g. truck order)	> Trucks disengage and keep contact with PSP



Source: Roland Berger; TNO

Large fleet operators will gain a competitive advantage as they are more likely to find platooning partners

Options for platooning collaboration



Owner operators

- > Less willingness to platoon with larger fleets
- > Unlikely to wait for platoon partner

Large fleets

- > Prefer platooning within own fleet
- > More likely to wait for platoon partner

Key insights

- > Platooning outside own fleet bears the risk to improve a competitors bottom-line
- > Large fleets have a competitive advantage as they can platoon within own fleet and also have stronger time latitude and can afford waiting for platooning partner

Source: Auburn University; Roland Berger

Your contacts at Roland Berger

Stephan Keese

Senior Partner Automotive, North America

Stephan.Keese @rolandberger.com

+1 312 385-0426

Dr. Wolfgang Bernhart

Senior Partner Automotive, Germany

wolfgang.bernhart @rolandberger.com

+49 160 744-7421

Norbert Dressler

Senior Partner Automotive, Germany

norbert.dressler @rolandberger.com

+49 160 744-7420

Markus Baum

Principal Automotive, Germany

markus.baum @rolandberger.com

+49 160 744-7121

Dr. Walter Rentzsch

Project Manager Automotive, North America

walter.rentzsch @rolandberger.com

+1 248 275-3851

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