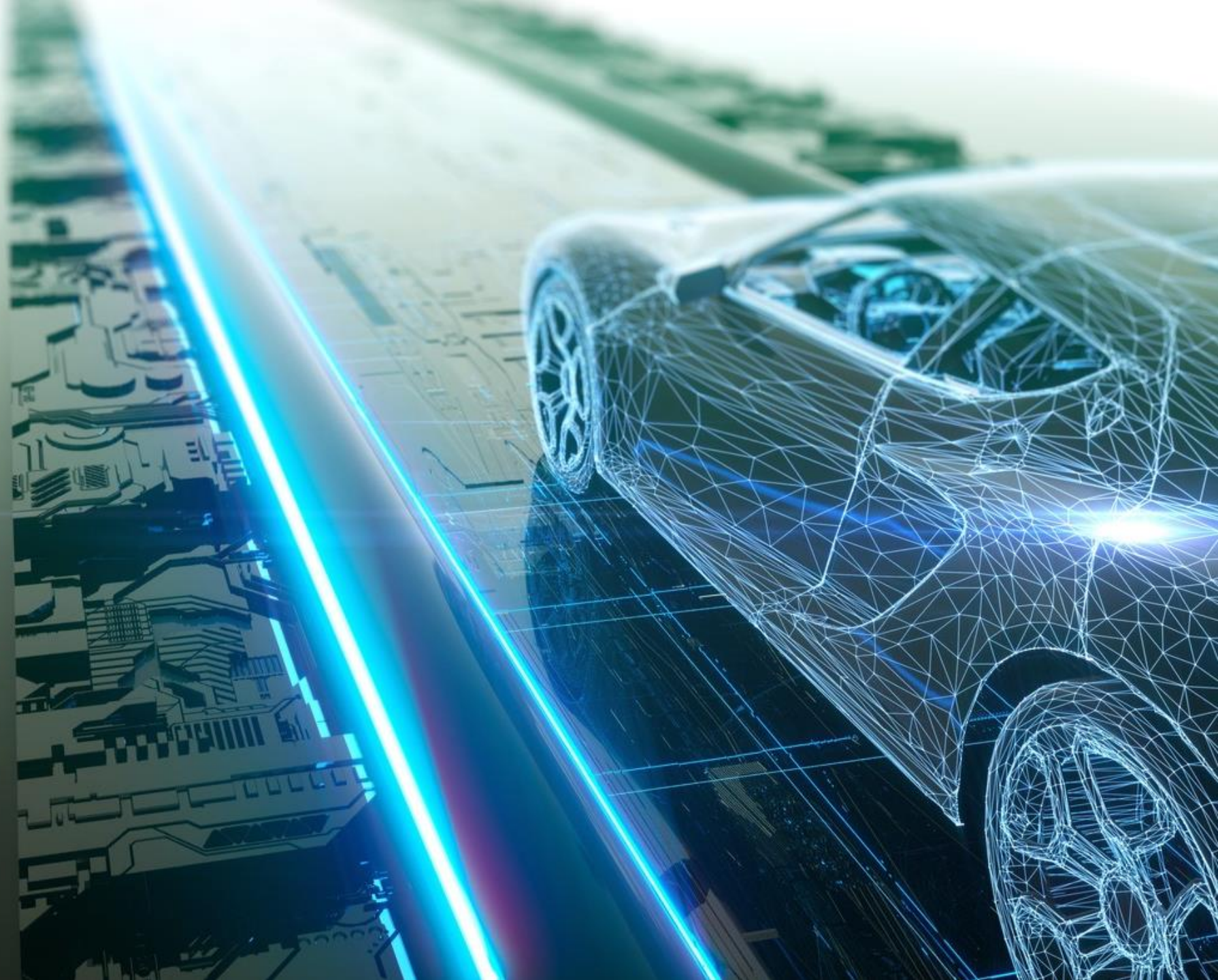
WORLD ECONOMIC FORUM

FUTURE NETWORKED CAR SYMPOSIUM

Vehicle autonomy: Where are we now? What is still missing?

Dr. Maria J. Alonso
Autonomous Systems Lead
World Economic Forum

24 March 2025



This presentation builds largely on outputs from the DRIVE-A: Vehicle Autonomy initiative work carried out in collaboration with the Boston Consulting Group.

World leaders face deep and complex shifts

Economic and industrial transformation

Geopolitical transformation

Technological transformation

Cultural and value transformation

The World Economic Forum is the International Organization for Public-Private Cooperation

> The world is undergoing deep, complex and accelerated transformation, and neither government, nor business, nor civil society alone can address our common challenges.

PROFESSOR KLAUS SCHWAB
FOUNDER OF THE WORLD ECONOMIC FORUM

Where are we now? Readiness across use cases

Four key distinct use cases

Focus of this presentation

Personal vehicles

EXPECTED BENEFITS

- Increase road safety by reducing human error
- Enhance convenience during travel

OWNERSHIP: Privately owned or leased

TECH LEVEL: Gradual development from ADAS (L0-L2+) to AD (L3/L4)

DOMAIN: Highway, suburban and urban

Robotaxis and roboshuttles

- Enhance the flexibility of public transport
- Reduce operational costs and improve accessibility

OWNERSHIP: Fleet providers own & operate

TECH LEVEL: Autonomy-first system development (L4)

DOMAIN: Suburban and urban

Autonomous trucks

- Address critical driver shortages
- Increase efficiency and flexibility with 24/7 uptime

OWNERSHIP: Fleet providers own & operate

TECH LEVEL: Autonomy-first system development (L4)

DOMAIN: Highway and suburban

Special purpose autonomous vehicles

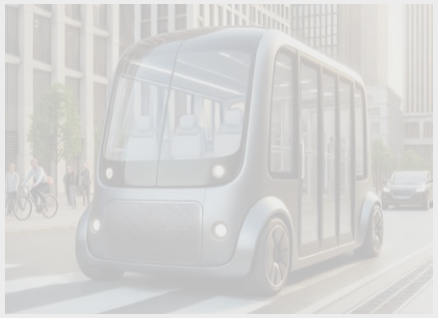
- Improve safety in hazardous environments
- Enhance efficiency for specialized tasks

OWNERSHIP: Specialist firms own & operate

TECH LEVEL: Autonomy-first system development (L4)

DOMAIN: Special environments

Four key distinct use cases

	Personal vehicles	Robotaxis and roboshuttles	Autonomous trucks	Special purpose autonomous vehicles
				
EXPECTED BENEFITS	• Increase road safety by reducing human error • Enhance convenience during travel	• Enhance the flexibility of public transport • Reduce operational costs and improve accessibility	• Address critical driver shortages • Increase efficiency and flexibility with 24/7 uptime	• Improve safety in hazardous environments • Enhance efficiency for specialized tasks
OWNERSHIP	Privately owned or leased	Fleet providers own & operate	Fleet providers own & operate	Specialist firms own & operate
TECH LEVEL	Gradual development from ADAS (L0-L2+) to AD (L3/L4)	Autonomy-first system development (L4)	Autonomy-first system development (L4)	Autonomy-first system development (L4)
DOMAIN	Highway, suburban and urban	Suburban and urban	Highway and suburban	Special environments

Five dimensions as backbone to assess scaling readiness

DEMAND

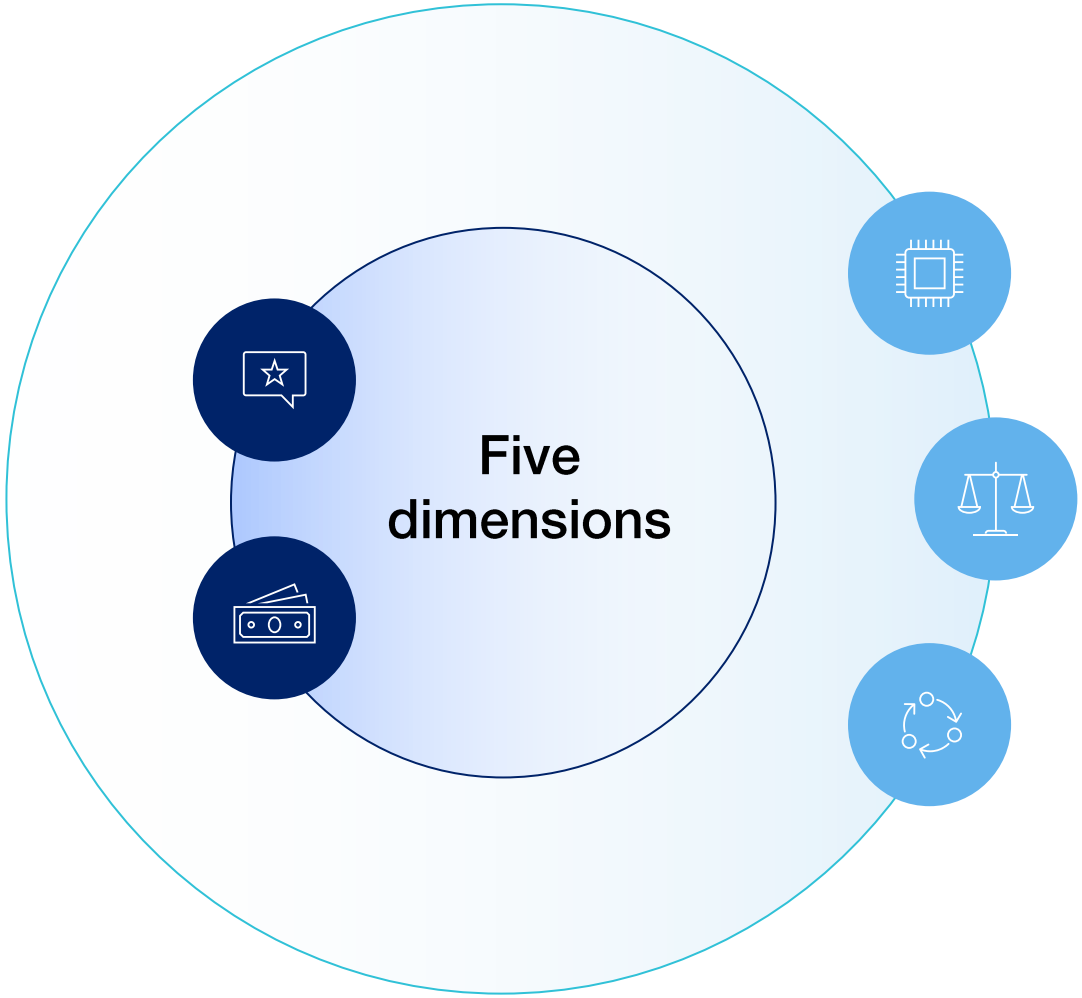
When will customers buy autonomous vehicles?

01. Consumers

- Consumer trust and interest
- Recurring system usage

02. Economics

- Projected ADAS/AD system prices
- Willingness-to-pay for ADAS/AD



SUPPLY

When will autonomous vehicles be available?

03. Technology

- Remaining technological obstacles
- Expected time to overcome obstacles

04. Regulation

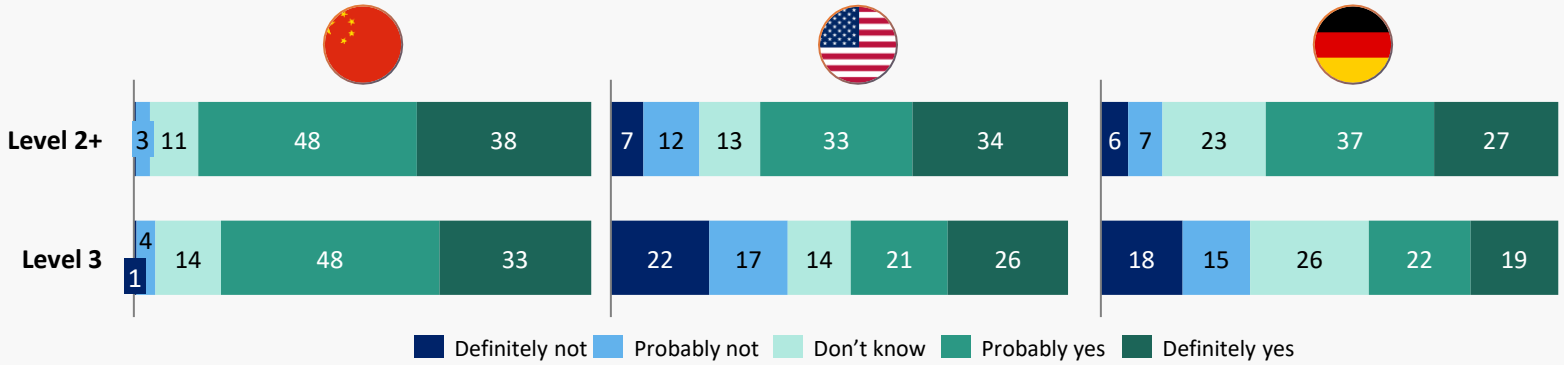
- Current regulatory status
- Anticipated regulatory changes

05. Ecosystem

- Deployment potential per OEM
- Ecosystem ramp-up to support scaling

Chinese consumers embrace AVs, backed by advanced tech, while others remain more hesitant

Q: How likely are you to consider each of these features for your next vehicle? [2023]



To continue building trust, three aspects must be considered:

- User experience
- Road safety
- Cybersecurity

4 out of 10 drivers claimed that they needed to intervene in recent ADAS experience

Sources: IIHS, BCG ADAS/AD Survey 2023 (N=1,929), BCG U.S. self-driving cars survey 2014 (N=1,510)

L2+ expected to dominate in the short term, gradual move to L4 once tech challenges are resolved

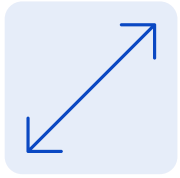
Three key tech challenges to be solved

Solve most important ODDs

Multiple ODDs (multimodal, snow, …) are still to be solved to provide functional L4

Select the right modeling approach

Debate persists if AVs should mimic human thinking or focus on solving edge cases



Ensure scalability across regions

Highly customized software per region makes global scalability a major challenge

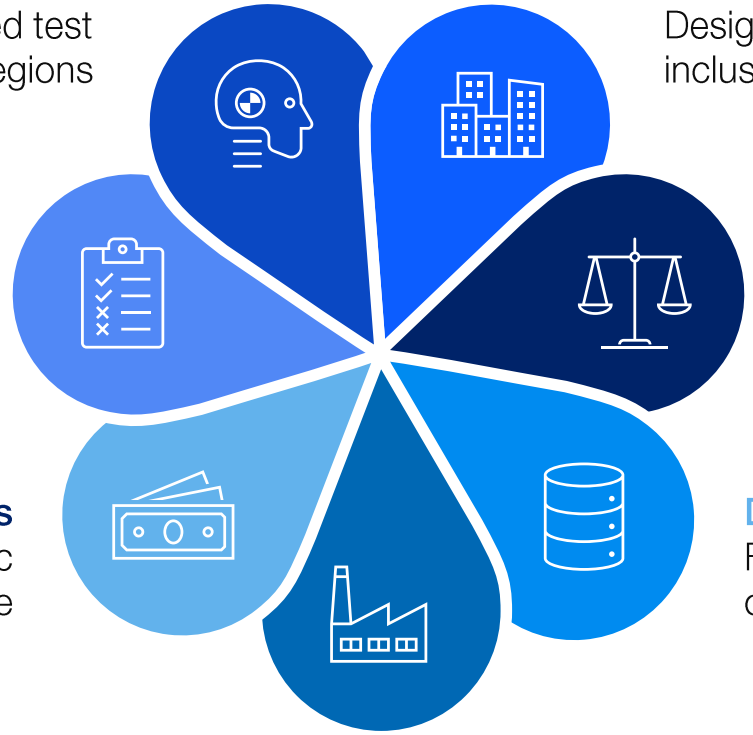
GenAI playing an increasing role in solving tech challenges.

While the black-box nature of AI results in safety concerns, recent breakthroughs seem to provide more interpretable and verifiable solutions.

Policy measures as comprehensive packages to foster safe scaling; moderate progress across most buckets in forerunning geographies

Test frameworks
Align on predictive and unified test frameworks across regions

Urban planning integration
Designate AV lanes, pick-up zones, and inclusion in transport systems



Homologation criteria
Define clear technical standards for AV performance and safety

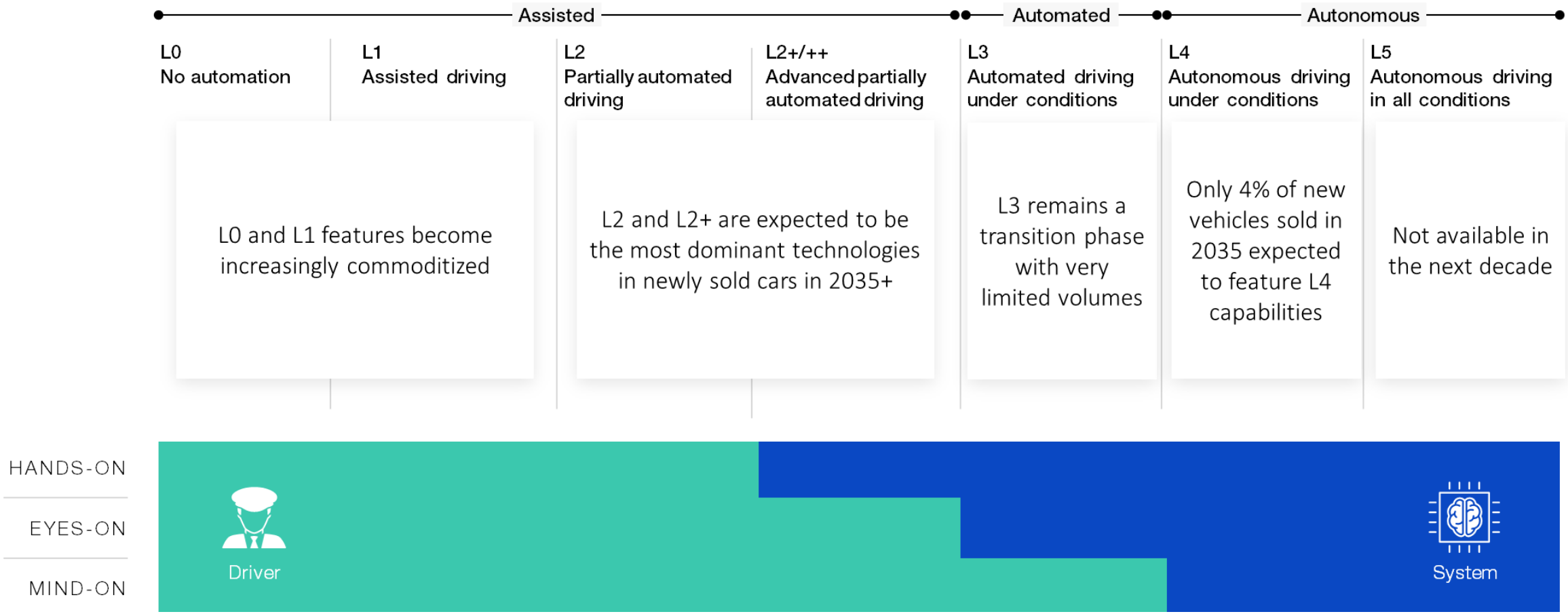
Liability frameworks
Define responsibility for system failures and during takeovers

Industrial policies
Foster ecosystem with domestic manufacturing and infrastructure

Data regulations
Foster purposeful data sharing & enforce cybersecurity

Incentives
Provide incentives like tax breaks and pilot project funding

Private ADAS/AD adoption is an evolution, with assisted vehicles, and not autonomous vehicles, dominating the next decade



Four key distinct use cases

	Personal vehicles	Robotaxis and roboshuttles	Autonomous trucks	Special purpose autonomous vehicles
				
EXPECTED BENEFITS	• Increase road safety by reducing human error • Enhance convenience during travel	• Enhance the flexibility of public transport • Reduce operational costs and improve accessibility	• Address critical driver shortages • Increase efficiency and flexibility with 24/7 uptime	• Improve safety in hazardous environments • Enhance efficiency for specialized tasks
OWNERSHIP	Privately owned or leased	Fleet providers own & operate	Fleet providers own & operate	Specialist firms own & operate
TECH LEVEL	Gradual development from ADAS (L0-L2+) to AD (L3/L4)	Autonomy-first system development (L4)	Autonomy-first system development (L4)	Autonomy-first system development (L4)
DOMAIN	Highway, suburban and urban	Suburban and urban	Highway and suburban	Special environments

The robotaxi hype: from revolution to evolution

Over-optimism 8-10 y ears ago…

Strong belief in near future of robotaxis and self-driving technology

- Elon Musk 2016

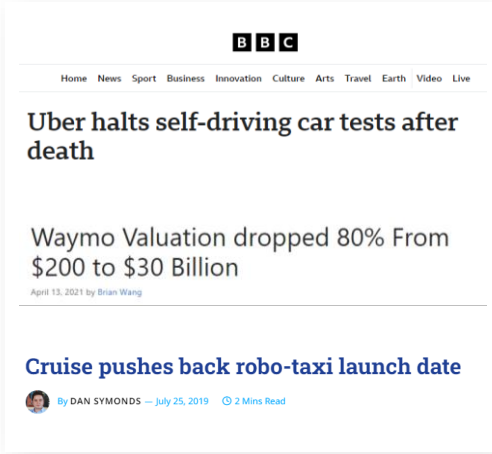
"I feel pretty good about the goal of a demonstration drive of full autonomy all the way from LA to New York. Basically from a home in LA to – let's say – dropping you off in Time Square in New York and then having the car park itself by the end of next year."

- Chris Urmson 2015

"We could see self-driving cars on the road by 2020 – my son could get his driver's license in 4.5 years, my team and I are committed to making sure that doesn't happen"

…Followed by the bursting bubble…

Accidents, slashed valuations, repeatedly delayed deadlines

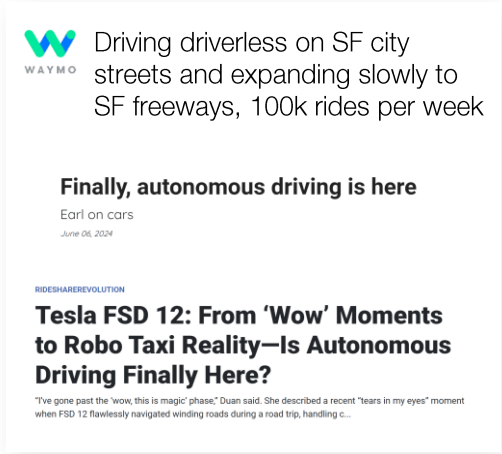


- Elon Musk, 2022

"I was wrong on some things… we will solve autonomy in 2024 and that should significantly reduce accidents"

…Now on path to enlightenment?

Very first driverless commercial operations, accompanied by loud noise



Quo vadis robotaxi - 6 questions decisive

SUPPLY

1. Entering | What (and how long) does it take for robotaxi players to enter a new city?

2. Scaling | How fast can robotaxi operators scale within a city?

DEMAND

3. Consumer | Will consumers really adopt to robotaxi usage?

4. Cities and modes | Where are the limits – which share of cities and modes can robotaxis grab?

ENABLER

5. TCO | Will robotaxis be a good business model? How does this differentiate across regions?

6. Ecosystem | What can OEMs, authorities, etc. do now to accelerate the robotaxi adoption?

Source: Press research

Operators entering only a hand full of cities; operational „preparation“ as major hurdle

Case studies, city expansion of cruise and Waymo

cruise

06/2022
Commercial (limited)
San Francisco, CA

1 year
1 city → 7 cities

07/2023
Commercial (limited)
San Francisco, CA
Phoenix, AZ
Austin, TX

Trials
Dallas, TX
Houston, TX
Miami, FL
Nashville, KY (planned)

WAYMO

10/2020
Commercial
Phoenix, AZ

4 years
1 city → 5 cities

08/2024
Commercial
Phoenix, AZ
San Francisco, CA
Los Angeles, CA (limited)

Trials
Austin, TX (planned)
Atlanta, GA (planned)

Major operational hurdles to enter a new city

- Regulatory approval including long & expensive preparatory collaboration with local authorities
- Infrastructure set-up incl. charging, parking, V2I, service fleet & staff, remote assistants
- Functioning digital mapping and localization ("ready to test")
- Fleet testing in real-world conditions (to gain final approval for operation)
- Launch and scaling incl. marketing & educational campaigns to prepare launch

→ ~2-3 years

Comments

Cruise expanded aggressively across many cities (6 new locations in ~1y) before having to pause operations after pedestrian incident in 2023. And Cruise being discontinued in 2024.

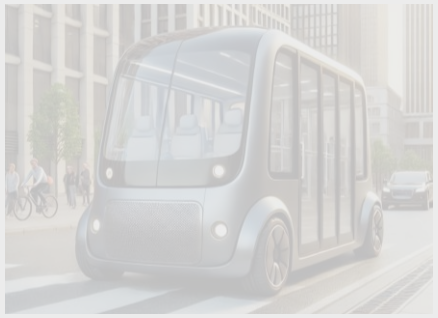
In contrast, **Waymo expands relatively defensively**, having added only 1 city (SF) for 3y before accelerating expansion.

Each stakeholder must deliver on their role for robotaxis at scale

	Role	Stakeholder	Tasks	At current trajectory, what is missing for scaling by 2030?
Production	Vehicles	OEMs	Develop and produce vehicles tailored for robotaxi usage	• Successful transformation to SDVs including new E/E architecture
	AD tech	HW and SW suppliers	Develop AD software and hardware customized to local needs	• Reliable safety performance across ODDs and regions • Easily scalable and affordable software
Enablers	Funding	VCs, strategic investors, public-private partnerships	Provide funding for R&D and scaling	• Secured funding for improving tech and scaling operations
	Regulation	Governments, authorities	Set regulation and homologation standards, provide licences, set zones	• Harmonized regulation across cities and countries
	Insurance	Insurances, risk analytics, reinsurance	Develop risk assessment models and policies	• Large-scale data availability for robust risk models and policies
Operations	Infrastructure	Utilities, cities	Provide charging, V2X, pick-up zones; integrate in-traffic control	• Dedicated inner-city robotaxi infrastructure (lanes, kerb spaces) • Integration in traffic management systems
	Fleet mgmt.	OEMs, suppliers, ride-hailing, fleet mgmt.	Handle fleets and maintenance, determine service areas	• Defined task distribution among OEMs, platforms, fleet management • Scalable fleet management frameworks
	Fleet control	OEMs, suppliers, ride-hailing, fleet mgmt.	Manage safety backup drivers, monitor fleet performance	• Defined task distribution among OEMs, platforms, fleet management • Dedicated fleet control centres with specialized staff
	Platform	Ride-hailing and MaaS platforms	Integrate robotaxis into platforms, ensure smooth interactions and support	• Defined customer journey and smooth processes • Integration with fleet management &andcontrol providers
Usage	Education	Public groups, media, universities	Educate on safety and benefits, advocate for equitable access	• Large-scale education on capabilities and limitations • Analysis of societal benefit of large-scale fleets
	Customer	B2B and B2C end users	Use robotaxis, engage in feedback loops	• Trust to share streets with robotaxis as well as use them

Ready to scale · Limited gaps · Major gaps

Four key distinct use cases

	Personal vehicles	Robotaxis and roboshuttles	Autonomous trucks	Special purpose autonomous vehicles
				
EXPECTED BENEFITS	• Increase road safety by reducing human error • Enhance convenience during travel	• Enhance the flexibility of public transport • Reduce operational costs and improve accessibility	• Address critical driver shortages • Increase efficiency and flexibility with 24/7 uptime	• Improve safety in hazardous environments • Enhance efficiency for specialized tasks
OWNERSHIP	Privately owned or leased	Fleet providers own & operate	Fleet providers own & operate	Specialist firms own & operate
TECH LEVEL	Gradual development from ADAS (L0-L2+) to AD (L3/L4)	Autonomy-first system development (L4)	Autonomy-first system development (L4)	Autonomy-first system development (L4)
DOMAIN	Highway, suburban and urban	Suburban and urban	Highway and suburban	Special environments

Highly automated driving (HAD)[1] to benefit the trucking industry in 3 ways

Use cases

Long-haul
≥ 500KM

Mid-distance H2H[2]
200~500KM

Mid-distance P2P[2]
200~500KM

Distribution
≤ 200KM

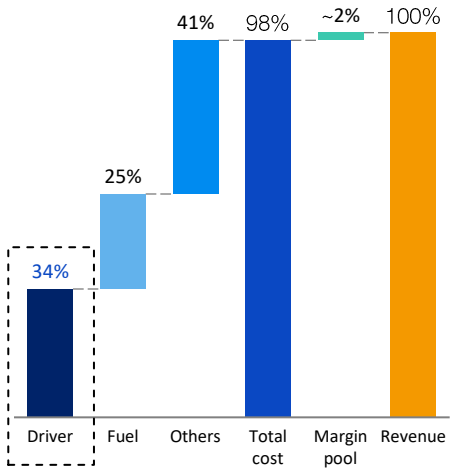
Vehicle types

MDT
6-15 tons

HDT > 15 tons

TCO[3] benefit

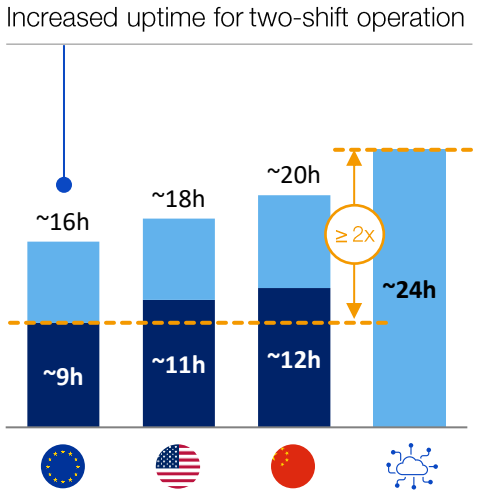
Long-haul trucking TCO in % (Germany)



Potential for > 34%+ TCO reduction from driver cost and driving efficiency gains

Uptime improvement

Max. regular daily drive time per truck



Further up to ≥ 2x uptime increase per vehicle due to avoidance of rest/brake times

Driver shortage relief

REUTERS
Britain's trucker shortage jams post-pandemic recovery

CNBC
After causing chaos in the UK, truck driver shortages could soon hit the rest of Europe

Handelsblatt
Versorgungsengpass droht – Allein in Deutschland fehlen derzeit 60.000 bis 80.000 Lkw-Fahrer

Économie
Shortage of drivers: French road hauliers can no longer recruit
It is not just in the UK that road hauliers are short of hands. France is also looking for drivers: between 40,000 to 50,000 people.

Resolution of driver shortages in numerous developed markets

1. Trucks with Level 4 driving capabilities on highways or in closed environments. 2. Hub-to-hub/Point-to-point. 3. Total cost of ownership
Sources: Press research

HAD readiness varies widely, driven by tech, regulation, and infrastructure

Use cases	Anticipated readiness by 2035			Rationale
	Technology	Regulation	Infrastructure	
 Long-haul hub-to-hub				▪ Fixed routes along highways align with L4 strengths ▪ Regulation is limited to selected routes, e.g., main TEN-T networks ▪ High-volume corridors need to be upgraded to enable AV operations
 Mid-distance hub-to-hub				▪ Less infrastructure needed than for long-haul, making AVs more likely ▪ Shorter routes are easier to regulate and equip for AD ▪ In other aspects, similar to long-haul hub-to-hub use case
 Mid-distance point-to-point				▪ Route variability strongly increase technological complexity ▪ Similar regulatory needs as for mid-distance hub-to-hub use case ▪ Infrastructure upgrades are more demanding than for hub-to-hub
 Intra-city distribution				▪ Tech readiness is largely dependent on progress in light vehicles ▪ Likelihood of risk of failure causing human harm will slow regulation ▪ Complex environments with many road users challenge developments
 Closed environment				▪ Autonomy is best suited to controlled environments and repetitive tasks ▪ Limited potential for human harm reduces the demand for regulation ▪ The operating area is restricted, widely mapped and monitored

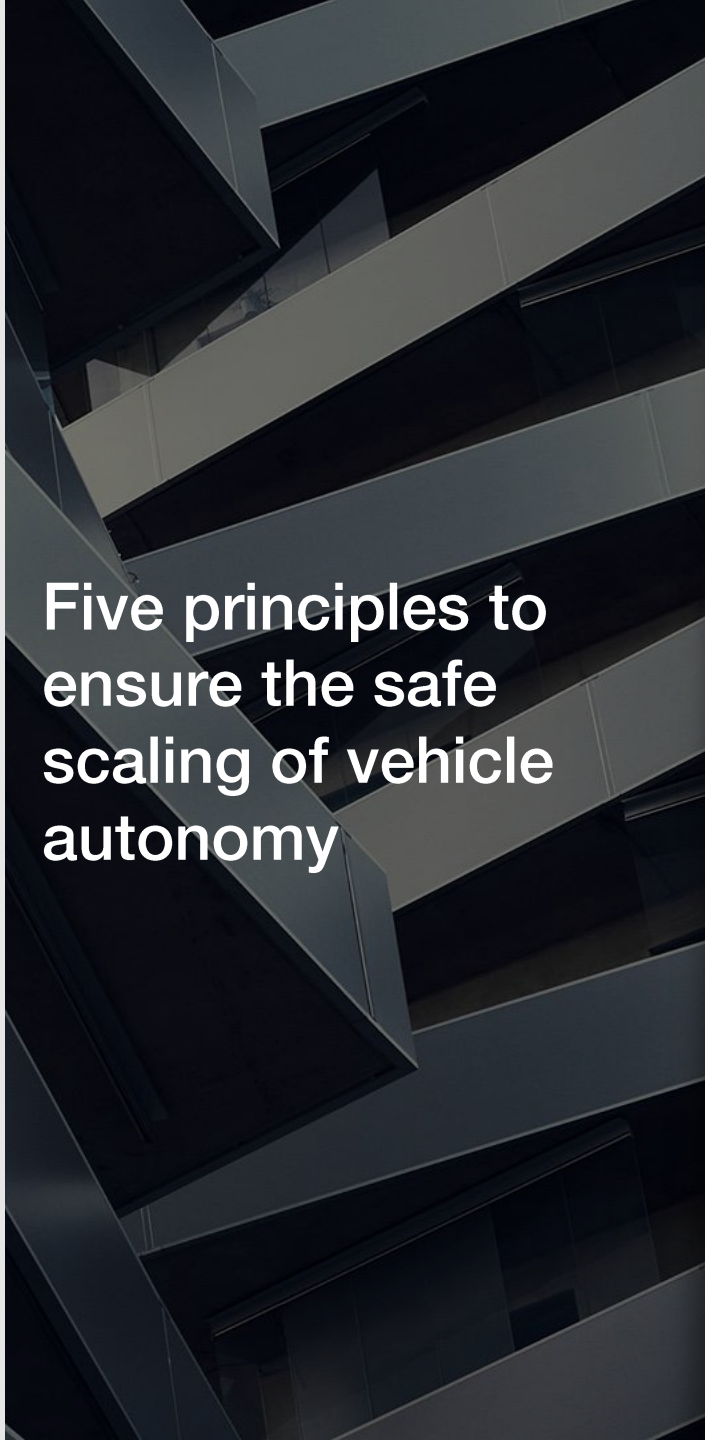
Each stakeholder must deliver on their role for HAD trucks at scale

	Role	Stakeholder	Tasks	At current trajectory, what is missing for scaling by 2030?
Production	Vehicles	OEMs	Develop and produce vehicles tailored for HAD usage	• HAD-dedicated trucks with respective E/E architecture
	AD tech	HW and SW suppliers	Develop AD software and hardware customized to local needs	• Reliable safety performance across ODDs and regions • Easily scalable and affordable software
Enablers	Funding	VCs, strategic investors	Provide funding for R&D	• Strong commitment across investors to HAD investment case
	Regulation	Governments, authorities	Set regulation and homologation standards, provide licenses, set zones	• Harmonized regulation across cities and countries
	Insurance	Insurances, risk analytics, reinsurance	Develop risk assessment models and policies	• Large-scale data availability for robust risk models and policies
Operations	Infrastructure	Utilities, cities	Charging, V2X, integration in traffic control	• Dedicated infrastructure for charging and V2X communication • Integration in traffic management systems
	Asset ownership	OEMs, leasing firms, 3PLs[1], fleet operators, cargo owner	Own HAD trucks, leasing to operators or self-operate	• Defined role and sales model (price/km, price/kg, etc.) • Ensured 24/7 uptime to leverage TCO benefits
	Fleet management	OEMs, AD suppliers, fleet operators, 3PLs	HAD control tower, (remote) maintenance, repairs	• Establish control tower (alerts, remote driving, etc.) processes • Facilities and staff along routes for emergency response
	Transport operator	Fleet operators, 3PLs, cargo owners	Warehouse network, unloading/loading, load pre-check	• Widely upgraded warehouse yards and loading docks • Upskilled workforce and processes for handling HAD trucks
	Digital platform	Freight platforms, AD suppliers, TMS firms[2]	Load matching, route optimization, fleet management, TMS integration	• Clear task distribution as multiple stakeholders strive for this role • Unified platform supporting multi-OEM fleets
Usage	Customer	Cargo owner	Book trucking services	• n/a – TCO benefits lead to high interest in HAD trucks

1. 3PL = 3rd party logistics (e.g., DHL, Schenker, FedEx). 2. TMS = transport management system

Ready to scale | Limited gaps | Major gaps

Collaboration to ensure the safe scaling of vehicle autonomy



Five principles to ensure the safe scaling of vehicle autonomy

#1 Enforce strong safety behaviours and transparency throughout organisations.

#2 Ensure consumers are well-informed about their responsibilities when using ADAS/AD features.

#3 Unify the industry around shared safety metrics that enhance trust and accountability.

#4 Collaborate closely with regulators to build trust and align on guidelines for autonomous technology deployments.

#5 Ensure the cybersecurity and resilience of autonomous systems to prevent disruptions from malicious attacks.

DRIVE-A Initiative

WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD