McKinsey & Company

Autonomous trucks – re-imagining supply chains and infrastructure

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The McKinsey Center for Future Mobility is the leading think tank on future mobility trends like Autonomous Vehicles

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About McKinsey Center for Future Mobility

Integrated, cross- industry perspective

360°

perspective covering all industries and institutions in the mobility ecosystem

Proprietary research & knowledge assets

~90

publications in the last 3 years, based on proprietary research

In- depth expertise

200k

hours of dedicated research each year by our researchers & practitioners

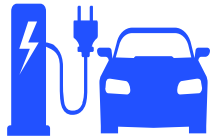
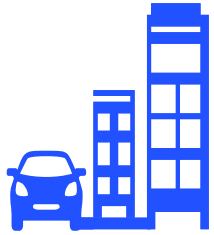
Network of world class thought leaders

20+

strategic private/public sector partners (e.g., C40, World Economic Forum, VDA)

Autonomous vehicles one of the major near-term mobility megatrends and have a deeply transformational impact

Focus of presentation

Future mobility trend	 **Autonomy**	 **Connectivity**	 **Electrification**	 **Shared mobility**	 **Advanced air mobility**
Current status of technology	Pilot / early commercialization	Well-established	Initial scaling	Well-established	R&D phase
Pace of future adoption	Inflection point in adoption post 2027	Moderate and stable growth	Growing but at slower rate	Moderate and stable growth	R&D phase
Level of disruption	Deeply transformational	Mostly incremental	Transformational	Slightly transformational	Deeply transformational

Setting the stage: Of the several autonomous technology applications, we focus today on Autonomous Trucking

Focus of presentation

	 Robotaxi-/shuttles	 ADAS/ Personal AD	 Autonomous Trucks	 AGVs / AV Off-road
Description	Shared vehicles that fully autonomously drive passengers to their desired target destination	Advanced Driver Assistant Systems (SAE L2) AVs, which handover responsibility to the driver (L3) or bring them-selves into a safe state (L4)	Fully autonomous trucks that can cover long distances without human interference	Fully autonomous guided vehicles (AGV) as well as AV off-road vehicles that operate fully driverless on e.g., sidewalks, construction or agricultural areas etc.
Operating Domain	Mainly urban environments	Initially highway expanding to rural roads and urban environments	Initially highway expanding to rural roads and urban environments	Initially highway expanding to rural roads and urban environments
AV Level	SAE Level 4/5	SAE Level 0 – 4	SAE Level 0 - 4	SAE Level 4/5
Status	Commercial offerings on road since 2020; plans of expanding to additional cities	Sizeable market for L2 First L3 cars available (e.g., Honda Legend, NIO ET7); first launches expected for 2024	In testing stage – initial tests ongoing in on pilot routes	AGVs and AV Off-road vehicles already in pilot and/or fully launched stage

1. Traffic Jam Pilot; 2. Highway pilot

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On-highway autonomous trucking will likely be the major unlock for supply chains

Focus of presentation

Use case	Description	Relative technical complexity	Estd. US market size[1] ('000 VIO)	Solution scalability and adoption
 **Hub-to-Hub**	Autonomous trucking for **middle-mile transportation** on **highways** between **two or more hubs** or **distribution centers** close to highways	High	~500	↗ • Rapid adoption growth driven by TCO savings and driver shortage • Scalable gradually, lane-by-lane • Solution can leverage existing logistics ecosystem for the most part
 **Ports & drayage**	**Ports/drayage:** Transport of **containers** within between shipping port and railyard, or DC to railyard **Yard hustler:** Transport from **containers** within **distribution center** premises or port premises	Medium	~100	↗ • Moderate-to-high TCO benefit • May require highly individualized solutions, e.g., mapping required for specific ports and Distribution Centers
 **Quarry & Mining**	Transport of **quarry/mining material** (or waste) between two points **within** a **confined quarry/mining site** or **from** a quarry/mining site to a **nearby end location**, e.g., port	Low	~40	↗ • Moderate TCO benefit • Highly specific solutions required for each individual quarry/mine • AV development supported by demand for electrification, achieved through down-sizing of vehicles

1. In terms of # of Autonomous Trucks in operation by 2035, base case scenario

Source: McKinsey Center for Future Mobility

Current state | ATs are beginning pilot applications on limited lanes, meaningful adoption growth likely 2027+

Autonomous truck technology started commercial operations recently …

Waabi ties up with Volvo to roll out self-driving trucks

Reuters, Feb 2025

Aurora's driverless trucks are making deliveries in Texas

- The Verge, May 2025

Volvo Autonomous TaaS Product to be known as Autona/freight

Transport Topics, May 2025

Aurora Begins Driverless Operations at Night and Opens Phoenix Terminal

Transport Topics, July 2025

Several metrics point to tech. improvement

~3.3 million

Autonomous truck miles driven by Aurora

~3.9 million

Annual miles driven, all autonomous trucks

~7300+

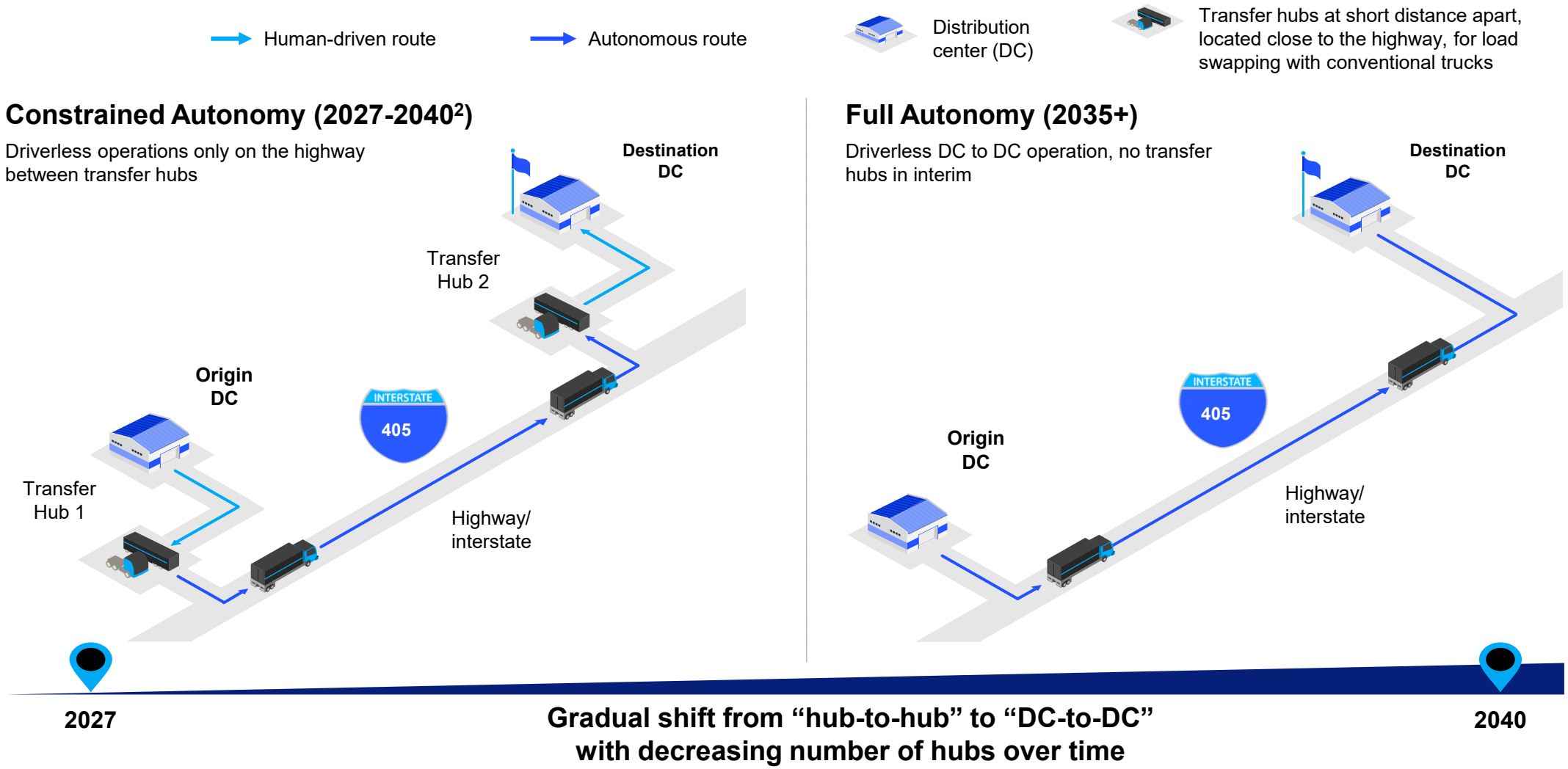
Loads delivered by Kodiak Autonomous trucks

Current state of the industry

- Autonomous trucks in driver-out mode commenced operations in mid 2025
- Currently volumes are in 'pilot phase', with a few tens of vehicles on the road
- Broader adoption is projected for 2027+ with constrained autonomy in hub-to-hub highway use-cases preceding full autonomy

Source: Press announcements, industry expert interviews and surveys

Deployment models | Near to medium term deployment on hub-to-hub model, longer-term gradual shift to DC-to-DC operation



1. DC = Distribution Center 2. number of distribution hubs required decreasing over time to 0

Source: McKinsey Center for Future Mobility

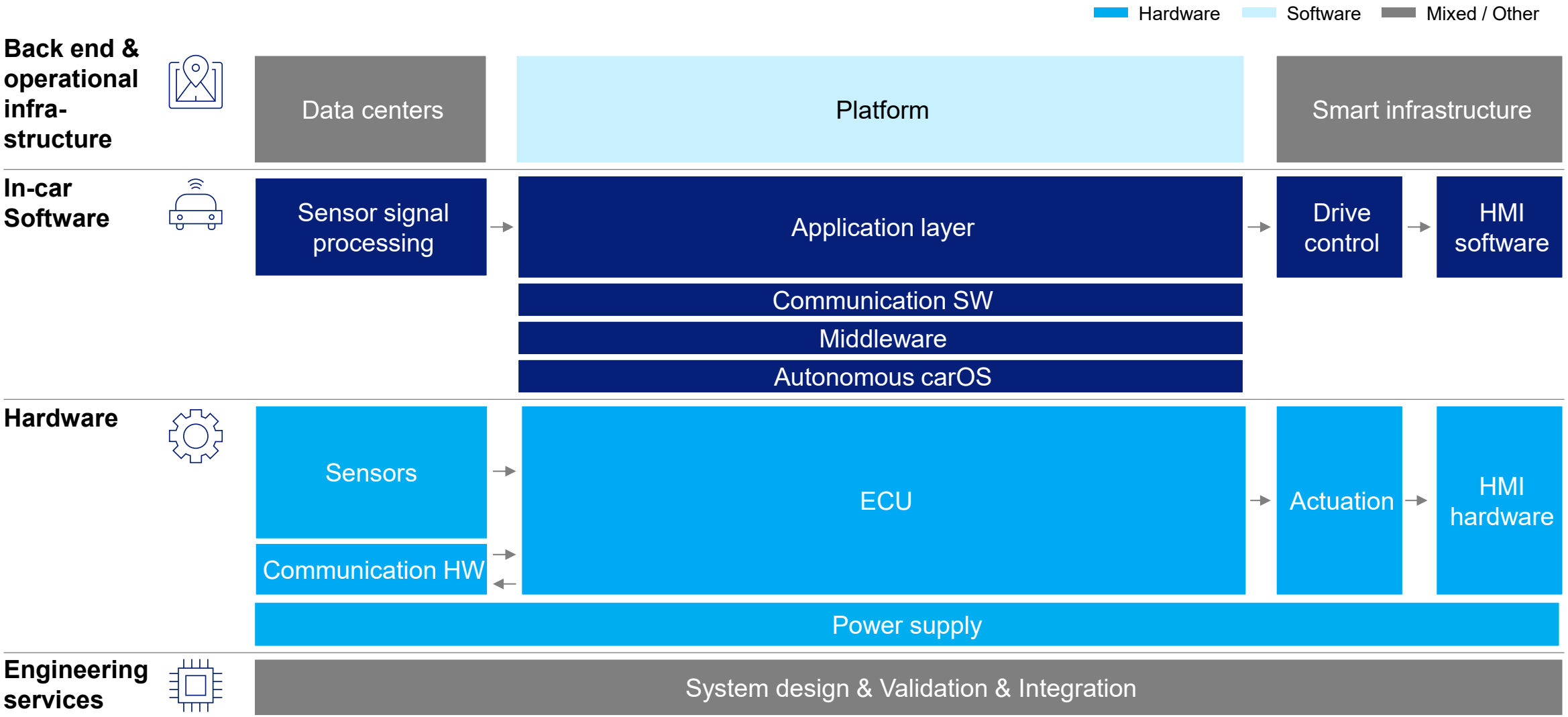
Future outlook | Technology readiness and TCO are the most important factors driving future adoption growth

Importance

	What you have to believe for future adoption growth
Technology	**Technology** (once validated/tested for commercial deployment) **can readily be scaled across fleets –** with ability to easily update/refresh software (e.g., FMS integrations with AV control centers) across deployments
Total cost of ownership (TCO)	**No significant increase in core AV HW costs** (e.g., LIDAR, compute, radar components) **and/or decrease in driver wages** that could drastically reduce ecosystem TCO benefits **Higher asset utilization and reduced driver cost** and other operating costs lead to attractive fleet ROI
Regulation/ legal	**More consistent regulation across states (US) that match geographies with positive AV tilt** (e.g., Texas, Florida, etc.) with minimal resourcing **Resolution across key laws/operating procedures for trucks to be adapted to AVs**
Union activity	**Labor unions will not derail autonomous trucking** — instead, they'll shape a **managed, negotiated rollout** that balances workforce transition with productivity gains For AV adoption to advance, the industry must align with unions on **new safety, training, and oversight standards** rather than push for outright labor replacement.
Supply chain	**Manufacturers of primary hardware components** (e.g., sensors, redundant braking/steering) **have scale for mass market AV solutions** – as different OEMs may source from similar providers as tech specs converge
Infrastructure	**Distribution centers/dedicated transfer hubs have requisite infrastructure** (e.g., loading/de-loading space, clear markers) at scale across both larger and smaller deployment routes as freight network expands

Source: McKinsey Center for Future Mobility

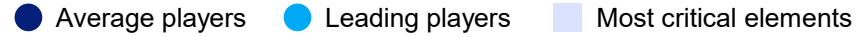
Technology maturity | Autonomous Vehicles operate on a complex technology Stack across hardware, software, infra and engineering services



Source: McKinsey Center for Future Mobility

Technology maturity | For multiple elements of tech-stack, commercial readiness is likely 2-3 years away

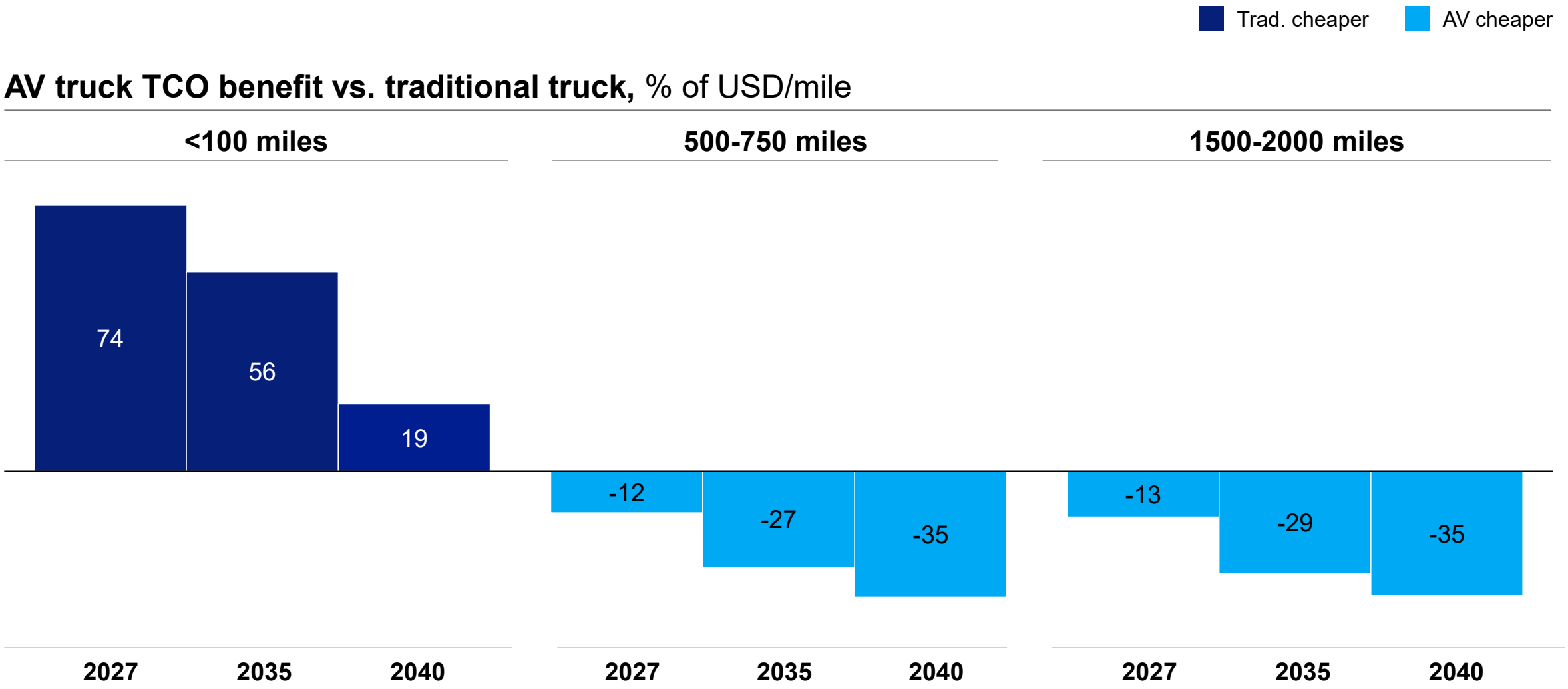
Example for L3/4 highway pilot



		Time to market (4 years until SOP … SOP ready)	Main challenges	Potential mitigation strategies
HW	Sensors		Required range and resolution to detect small objects on the road; LiDAR costs	Selection of sensor supplier with advanced technology; Tier-1 for industrialization
	Computing		Mobileye EyeQ5 available, but black box; Cost of high performance CPUs/GPUs	Usage of specialized ASIC chips; joint chip development with supplier (HW-SW co-design)
	Actuation		High costs for fail operational power supply and communication	Usage of advanced E/E architecture e.g., with Ethernet ringbus
SW	OS/Middleware		Functional safety of OS/Middleware	Working with suppliers with ASIL-D certified OS/MW solutions
	Localization		Localization in areas with low number of landmarks	Combination of (differential) GPS, high precise IMU, and landmarked based localization
	Object detection		Object detection in difficult weather/ light situations; Edge cases	Using LiDAR, camera, and radar
	Prediction		Prediction of human behavior, esp. in edge cases	CI/CD software development tools Building up simulation tools Focus data collection on edge cases
	Decision making/ path planning		Decision making/path planning in edge case	
Cloud	HD maps		Up-to-dateness of HD maps	Selection of HD-map supplier with superior crowd-sourcing capabilities
	Data collection, storage, processing		High amount of data required (>10 mn kilometers)	Partnering with major cloud provider
Engineering	Safety concept		ASIL-D requirements for all HW/SW	Hiring of functional safety experts or hiring of external advisors
	Validation methodology		Several mn miles of testing leading to high costs	Building-up simulation tools Discussing validation methodologies with regulators

Source: McKinsey Center for Future Mobility

TCO savings | AV trucks are favorable on TCO vs. traditional trucks for long-distance trucking



Source: McKinsey Center for Future Mobility

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Autonomy would likely impact different parts of the supply chain network in diverse ways

A Large storage facility

Large storage facilities will expand in scale and reach, enabled by lower middle-mile costs and connected to DCs up to 2,000 miles by AVs

They will cluster closer to supply to reduce man-driven miles, with **layouts purpose-built** for high-density AI-driven automation

B Transfer hubs

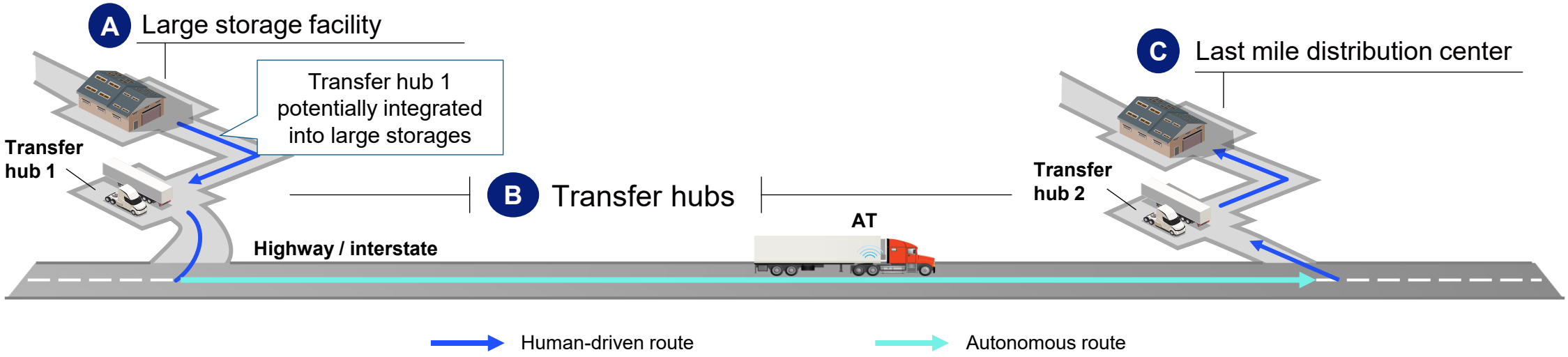
Transfer hubs will emerge as critical "cross-dock" interface nodes between autonomous and human-driven networks

Located **near highway interchanges**, they will operate 24/7 with AV charging, data offload, and maintenance capabilities—becoming essential infrastructure for early-stage autonomy

C Last-mile DCs

Last-mile distribution centers will become smaller, faster, and closer to consumers

Enabled by AV restocking, AI forecasting, and robotics, these high-velocity nodes will operate with **reduced inventory, high automation, and dense urban placement** to deliver faster fulfillment



Large storage facilities will likely need to get larger in size, and be co-located with or near upstream supply

	From	To	Specific impact of Autonomy
Network role 	Regional bulk warehouse serving region; limited integration with downstream network	Storage facility connected to DCs up to 2,000 miles away via AV trucking corridors	Reduction of middle-mile transport costs from autonomy pushes storage closer to production and further from downstream DCs, minimizing man-driven hours
Location 	Distributed across regional markets to balance proximity and land cost	Co-located with or near upstream supply to minimize man-driven miles	Same as above
Design 	Manual warehouse layouts, wide aisles, limited automation infrastructure	AV Truck optimized layout with docking facilities, high connectivity and high power access in case of electric AV yard hostlers	Docking facilities prepare for AV Trucks Electric Autonomous yard hostlers require high power charging for continuous nearly-24x7 operation
Size 	Typical footprint ~500k–750k sq ft, sized for manual handling and labor access	Mega-facilities exceeding 1M sq ft	AV Trucking expands effective reach of storage with middle mile cost reduction

What experts are saying	"Networks are shifting to a 'barbell' model — a few large central hubs and many small automated local sites, with mid-sized warehouses fading away" – E-Commerce warehousing expert	"All of the rule of thumb ratios need to be reevaluated, in terms of space, like width of an aisle" – Logistics expert

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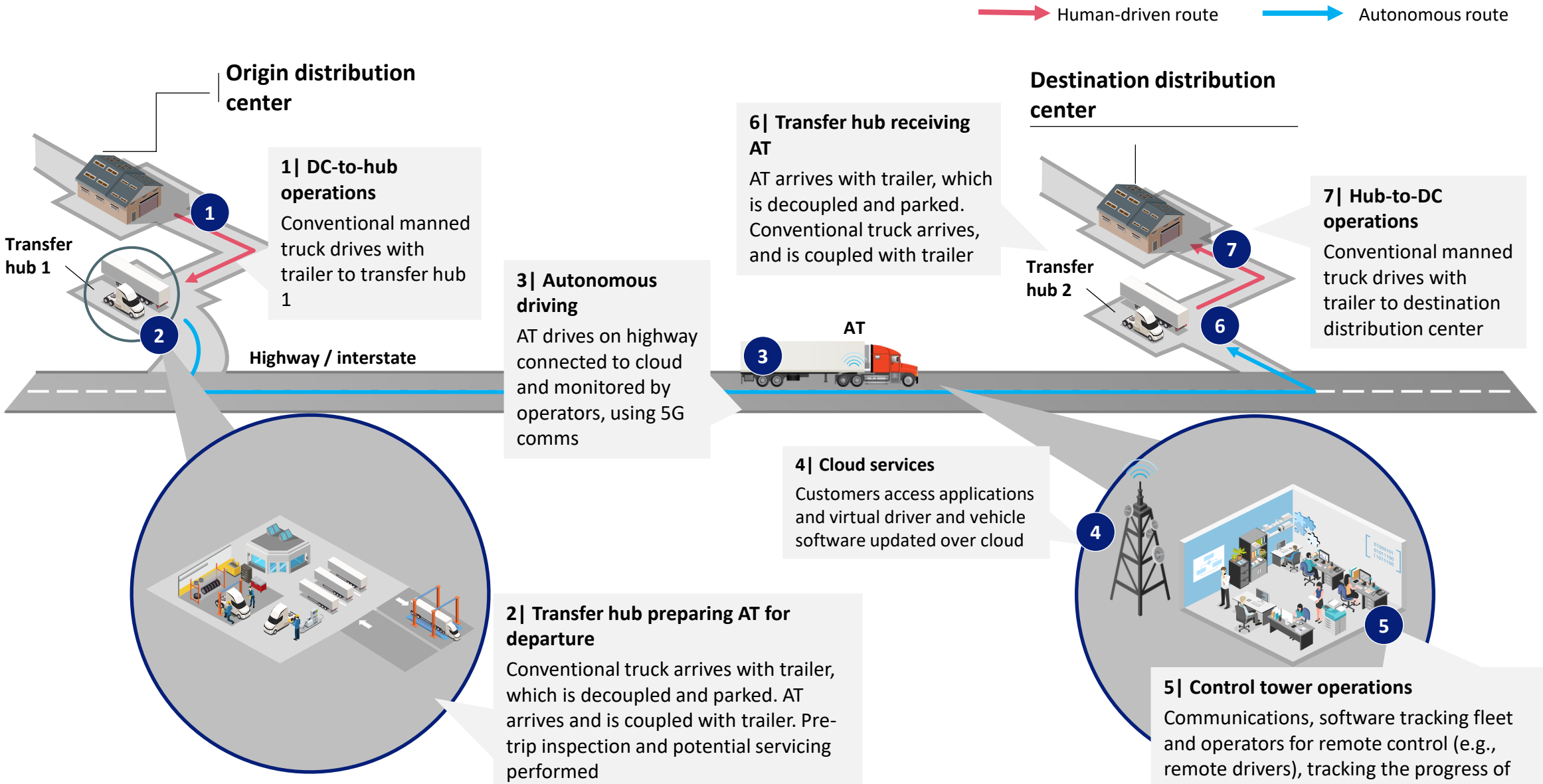
Broad ecosystem needed to enable hub-to-hub use-case and business model



Source: McKinsey Center for Future Mobility

To support autonomy, infrastructure will need to evolve in waves – from table-stakes physical layer to future digital layer

Physical infrastructure

- **Roads:** well-maintained with high-quality, clearly visible, and consistent markings that are radar-reflective
- **Signage:** clear, standardized, and potentially machine-readable codes for AVs to easily interpret
- **Lanes:** Dedicated lanes for AVs may improve safety and reduce interactions with human-driven vehicles
- **Real estate:** For transfer hubs as close as possible to the interstate highways, and remote autonomous network monitoring centers

Smart, digital infrastructure

- **Connectivity:** Widespread, high-speed, and low-latency networks
- **Vehicle-to-everything (V2X) communication:** for sharing data with traffic signals, other vehicles and roadside sensors
- **Roadside sensors:** cameras, lidar, and radar placed along roadways may provide additional data to enhance awareness
- **Cybersecurity:** A strong cybersecurity framework to protect the network from hacking and ensure the safety and integrity of the data being transmitted

Source: McKinsey Center for Future Mobility

Thank you!

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Additional research from **McKinsey Center for Future Mobility:**

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