McKinsey & Company

McKinsey Technology Trends Outlook 2022

Future of mobility

August 2022

What is the trend about?

Mobility is undergoing its **“second great inflection point”**—a shift toward autonomous, connected, electric, and smart (ACES) technologies

This shift promises to disrupt markets while improving **efficiency and sustainability** of land and air transportation of people and goods

Mobility is defined by several arenas across 4 disruptive dimensions of mobility **(ACES) and adjacent technologies** that enable more sustainable and efficient transportation

ACES

Autonomous technologies

Automated systems with sensors, AI, and analytical capabilities able to make independent decisions based on the data they collect

Connected-vehicle technologies

Equipment, applications, and systems that use vehicle-to-everything communications to address safety, system efficiency, and mobility on roadways

Electrification technologies

Solutions replacing vehicle components that operate on a conventional energy source with those that operate on electricity

Smart mobility solutions

Hardware and advanced digital/ analytics solutions enabling use of alternative forms of transportation (eg, shared-mobility solutions) in addition to or instead of owning a gas-powered car

Adjacent technologies

Lightweight technologies

Incorporation of new materials (eg, carbon fiber) and processes (eg, engine downsizing) to boost fuel efficiency and improve transportation sustainability

Value chain decarbonization

Technical levers to abate emissions from materials production and end-to-end manufacturing process and increase use of recycled materials across the value chain

Source: McKinsey analysis

Why should leaders pay attention?

Physical supply chains are vital to many industries, and today transportation is at a major inflection point, as mobility ecosystems are **simultaneously affected by regulation, shifting consumer preferences, and technology disruption**

1. Regulation is enabling a mobility revolution

Carbon targets and subsidies

50%

Amount by which emission targets for 2030 could be tightened by the EU

Urban access regulation

150+

Number of EU cities with access regulation for low-emission vehicles and pollution emergencies

2. Consumers are accepting new mobility solutions

Alternative ownership models

2/3

Portion of US consumers expecting their use of shared mobility to increase in next 2 years

Greener attitude

60%

Year-over-year increase in inner-city trips with shared bikes and scooters (136 million trips in 2019)

3. Technology disruption is happening at an unprecedented pace, and availability challenges remain

Autonomous driving

8x

Increase in average annual investments in autonomous vehicles over past 5 years

Connectivity

6 months

Length of delays in some recent vehicle launches due to software integration issues

Electrification

1:1

Cost parity for small EVs[1] with ICE[2] today, with fuel-cell parity expected by 2030

Smart mobility

50%

Portion of miles traveled with shared transportation modes expected by 2030

[1]Electric vehicles.
[2]Internal combustion engine.

Source: McKinsey analysis

What are the most noteworthy technologies?

ACES

Autonomy

- Radar and camera
- Lidar
- Steer/brake/shift-by-wire
- HD maps plus SLAM[1]
- Object detection
- Driving strategy

Connected vehicle

- Infotainment
- Vehicle-to-infrastructure (V2I) connectivity
- Cybersecurity

Electrification

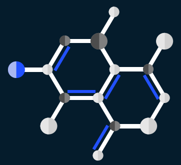
- Digital twin
- Lithium-ion battery (LIB)
- Beyond LIB
- Battery analytics
- Hydrogen fuel cells
- Hybrid propulsion

Smart mobility

- Transportation demand management (TDM)

Hardware | Software/AI

Adjacent tech



Lightweight technologies

- Advanced composites
- Advanced ceramics
- Metamaterials
- Nanomaterials

Value chain decarbonization

- Green primary materials
- Parts and materials circularity

[1]High-definition maps and simultaneous localization and mapping.
Source: McKinsey analysis

What are the most noteworthy technologies? (continued)

Hardware | Software/AI

	Tech cluster	Technologies	Description
ACES	Autonomous	Radar and camera (Hardware)	Sensor with algorithms to automatically detect objects, classify them, and determine the distance from them
		Lidar (Hardware)	Range detection system relying on light travel time measurement
		Steer/brake/shift-by-wire (Hardware)	Electrical or electromechanical systems for vehicle functions traditionally achieved by mechanical linkages
		HD maps plus SLAM (Software/AI)	Simultaneous mapping and localization solution to map out unknown environments
		Object detection (Software/AI)	Perception technologies used for behavior planning, route planning, motion planning
		Driving strategy (Software/AI)	Solutions integrating hardware and software components in a full-stack autonomous vehicle
	Connected vehicle	Infotainment	In-vehicle infotainment solutions (eg, augmented reality, voice recognition, and gesture control)
		V2I connectivity	Software and hardware enabling vehicle-to-infrastructure (V2I) connectivity
		Cybersecurity	Security solutions to protect connected cars and commercial vehicles against cyberattacks (eg, encoding)
	Electrification	Digital twin	Real-time virtual model of a system or process mirroring key attributes of the existing power infrastructure
		Lithium-ion battery (LIB)	Advanced battery technology that uses lithium ion as a key component of its electrochemistry
		Beyond LIB	Sodium-ion (Na-ion) and potassium-ion (K-ion) batteries, which might solve the resource issues facing LIBs
		Battery analytics	Intelligence to extend battery life, improve manufacturing, unlock end-of-life markets, prevent safety hazards
		Hydrogen fuel cells	Propulsion system where energy stored as hydrogen is converted to electricity by the fuel cell
		Hybrid propulsion	Propulsion system including several propulsion sources used either together or alternately (eg, fuel–electric)
	Smart mobility	Transportation demand management (TDM)	Solutions optimizing use of locally available transportation resources to incentivize transition to more efficient and sustainable modes of commuting
Adjacent tech	Lightweight technologies	Advanced composites	Polymer matrix composites with unusually high strength or stiffness (eg, carbon fiber)
		Advanced ceramics	Advanced composites such as carbon-fiber-reinforced plastics, which could substitute for steel
		Metamaterials	Materials measuring 10–100 nanometers in at least 1 dimension (eg, graphene or carbon nanotubes)
		Nanomaterials	Engineered materials that have properties not found in nature and that can modify wave properties
	Value chain decarbonization	Green primary materials	Green steel, carbon-reduced production technologies, green aluminum, and green plastics[1]
		Parts and materials circularity	Reuse, refurbishment, remanufacturing of modules or parts, and recovery of high-quality materials from end-of-life vehicles and other products to enable low-carbon vehicle production

[1]Green steel is made with mass balancing or innovative technology. Carbon-reduced production technologies include using direct reduced iron (DRI) and an electric arc furnace (EAF). Green aluminum is made with more widespread use of renewable electricity in smelters and multiple technology innovations flushing out most of the residual production emissions over the next decade. Green plastics include those made from bio-based feedstock and electrified production assets.

Source: McKinsey analysis

What disruptions could the trend enable?

Ground transportation

	With driver	Autonomous
Passenger transport	Advanced driver assistance systems (ADAS), ie, autonomy level of L2 and below[1] Dynamic shuttle services/ pooled e-hailing Peer-to-peer mobility (including car sharing)	Autonomous vehicles (eg, Level 3 or higher autonomy,[1] robo-taxis) Hyperloop
Transport of goods	Same-day delivery Trucking marketplace[2]	Autonomous trucks Last-mile delivery solutions (eg, last-mile robots on road or sidewalk)

Air mobility

	Crewed	Uncrewed
Passenger transport	Vertical takeoff and landing (VTOL) air taxis (crewed and uncrewed) Wingless multicopters (crewed and uncrewed) Supersonic/hypersonic air transport	Vertical takeoff and landing (VTOL) air taxis Wingless multicopters
Transport of goods	Conventional air freight with novel propulsion	Unmanned aerial vehicles, such as freight or delivery drones Unmanned traffic management systems

[1]Autonomy is categorized across level of supervision needed: L1 is execution of steering and acceleration/deceleration; L2 is monitoring of driving environment; L3 is fallback performance of dynamic driving tasks; L4 is system capability (ie, driving modes).
[2]With AI to manage logistics networks and fleet parks.

Source: McKinsey analysis

What industries are most affected by the trend?

Among the **most affected industries** are automotive and assembly; aviation, travel, and logistics; and telecommunications

Industry affected	Implications of technology trend
Automotive and assembly	• **Changing pockets of growth** as a revolution in urban mobility creates a shift from personal ownership to shared vehicles (global vehicle sales volume is at best projected to remain constant through 2030) • **Exploration of new mobility verticals** and **operating models** to take part in the novel mobility solutions arena • Drastic **increase in OEM market entrants** after decades of primarily mature-player presence • **Increased investment in tech R&D and ecosystem partnerships** (revenues from ACES may account for 1/5 of OEM value pool by 2030)
Aviation, travel, and logistics	• Improvements in **operational setup**, with higher asset utilization, increased flexibility, improved safety • **New business models**, as asset ownership may shift from small carriers to large integrators • **Shift of volume from rail to road** as cost advantage shifts to longer distances with autonomous trucks • Improved **efficiency of public transport** from dynamic shuttle services and pooled e-hailing
Telecommun-ications	• **Significant pressure for higher bandwidth** as mobility fuels exponential growth in data traffic and for **global coverage** to meet the need for vehicles to be connected everywhere, at all times • **New opportunities for telcos to monetize value-added services** (eg, by combining core connectivity with vehicular technologies and real-time mobility data)
Aerospace and defense	• **New modes of aerial transportation** of passengers and goods (eg, aerial autonomy for freight delivery, small size VTOL enabling air taxis) which will expand aviation use cases • **Novel propulsion** drastically changing unit economics • **Security pressure** as in-vehicle systems and connected infrastructure are more exposed to security threats

Source: McKinsey analysis

What industries are most affected by the trend? (continued)

Diverse stakeholders across industries are experiencing **second-order implications** of novel transportation technologies. Disruption is primarily driven by **macroeconomic impact**, changes in **resource demand patterns**, novel **modes of transportation,** and changes to vehicle **ownership models**, as well as **shifting value pools**

Industry affected	Implications of technology trend
Metals and mining	Change in material usage patterns (eg. steel for new powertrain types) and increased demand for sustainable materials (eg. green steel, green aluminum)
Electric power, natural gas, and utilities	Need for more generation capacity and for reinforcement of transmission and distribution networks to meet increased demand for electricity from EVs
Information technology and electronics	Increased demand for solutions enabling, supporting, and integrating technological advancements across ACES
Financial services	Change in claims portfolio (eg. impact of increasing car safety with ADAS and autonomous-vehicle systems)
Oil and gas	Change in demand for gasoline and diesel once EVs reach critical scale
Retail	Novel modes of delivery with airborne drones
Public and social sectors	Changes in city infrastructure from sustainability-focused regulation promoting smart mobility Revisions to land-use planning (eg. autonomous vehicles and shared mobility reducing the need for parking lots)

Source: McKinsey analysis

What are some use cases for the technologies that drive this trend?

Function-specific use cases

Function affected	Technology use case
Transportation of goods	• Autonomous trucks in long- haul supply chain • Freight drones for last-mile delivery • Supply chain optimization solutions enabling same-day delivery • Trucking marketplaces for efficient freight management
Transportation of people	• Novel mobility services such as robo-taxis • Purpose-built vehicles with longer durability (eg, designed specifically for shared mobility)

Industry use cases

Industry affected	Technology use case
Electric power, natural gas, and utilities	• Vehicle-to-grid systems (in which EVs return excess electricity back to the grid or throttle their charging rate)
Information technology and electronics	• Software/AI solutions for simultaneous mapping and localization, object detection, driving strategy • Hardware for autonomous vehicles (eg, lidars, cameras)
Public and social sectors	• Mobility-as-a-service for integrated commuter experiences across public transit, ride sharing, and micromobility • Congestion pricing (ie, dynamic pricing based on traffic)
Financial services	• Personalized insurance rates based on driving patterns from connected-vehicle data • New insurance use cases for autonomous vehicles (eg, insurance for vehicle intelligence)
Media and entertainment	• Novel ways of engaging a passenger during commute

Source: McKinsey analysis

Who has successfully created impact with these technologies?

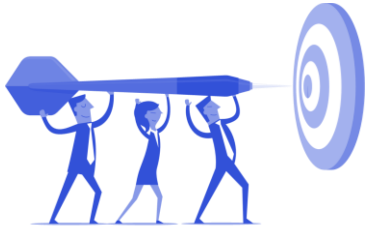
Industry	Mobility technology	Example company	Disruption caused by technology
 **Aviation, travel, and logistics**	Autonomous trucks	**UPS** **TuSimple**	**Environmental benefits and fuel savings:** TuSimple partnership with UPS North American Air Freight has delivered >13% fuel savings,[1] with potential to lower customers' freight costs significantly
 **Automotive and assembly**	Advanced driver assistance systems	**BMW**	**Safer driving:** BMW's Driving Assistance package cut property damage claims 27%, bodily injury claims 37%, and collision claims 6%[2]
 **Telecom-munications**	Connected vehicles	**Deutsche Telekom**	**New revenue streams:** DT is actively codeveloping connected-vehicle solutions in partnership with OEMs and identifying new customer connectivity needs (eg, Wi-Fi hotspot within BMW ConnectedDrive)
 **Electric power, natural gas, and utilities**	Electrification of vehicles	**E.ON**	**Business diversification:** In 2016, E.ON established a business unit to expand EV-charging infrastructure in the EU, signaling a strategic focus on e-mobility
 **Information technology and electronics**	Smart mobility	**The Routing Company**	**Dynamic public transit:** TRC offers an on-demand vehicle routing and management platform for cities to power the future of public transit
 **Metals and mining**	Lightweight materials	**General Motors** **Caltech** **Boeing** **UC Irvine**	**Efficient aviation**: "Microlattice" metal, codeveloped by Boeing, Caltech, GM, and UC Irvine, is reported to be 100x lighter than Styrofoam but strong enough to be used in structural components of airplanes[3]

[1]Savings achieved when operating in the optimal long-haul operating band of 55–68 miles per hour. | [2]Package includes forward collision and lane departure warnings, autobraking, and adaptive cruise control.
[3]In the case of the Boeing 787-9, which burns approximately 5,400 liters of fuel per hour, a 10–12% improvement in fuel economy amounts to 540–650 liters saved per hour.

Source: McKinsey analysis

What should leaders consider when engaging with the trend?

Benefits



Cost savings from supply chain improvements

Market expansion from reaching new customer segments in otherwise unserviceable locations or with improved delivery speed

Sustainability as new modes of ground and air mobility prioritize electric, hydrogen-based, or hybrid propulsion

Risks and uncertainties

Safety and accountability concerns surround uncrewed and autonomous mobility technologies

Technology uncertainties about batteries with sufficient range to support more applications (such as air mobility) may hinder greater adoption

Customer perceptions of noise and visual impact remain in play

Equipment and infrastructure costs are factors for new modes of transportation

Regulation shifts will occur as mainstream certification frameworks are developed

Privacy and security concerns for underlying algorithms and workflows must be addressed

Source: McKinsey analysis

What are some topics of debate related to the trend?

Ground transportation | Air mobility

1 Market penetration and timing of autonomy

What share of vehicle sales will autonomous vehicles account for?

While autonomy offers significant benefits (eg, reduction in traffic deaths, improvements in fuel economy), widespread adoption may be hindered by safety concerns (eg, several high-profile accidents), data protection issues, high upfront costs (vehicles and infrastructure), and insufficient regulation

2 Future of smart mobility in cities

How will future-of-mobility trends shape cities?

Smart mobility reduces traffic congestion and air and noise pollution, and it improves safety, speed, and cost of travel; however, urban infrastructure plans are often criticized for imposing heavy investment requirements and creating security/privacy concerns

3 Impact of shared mobility

Will advancements in shared mobility deliver on hoped-for financial and environmental impact?

Shared mobility has not yet proved its long-term economic viability, as many operators struggle with profitability; further, shared mobility must prove its sustainability impact as a full replacement for private cars, with an associated shift away from private-vehicle ownership (rather than its primary role today as an extension of private vehicles, thereby increasing the vehicle fleet)

4 Timing for new aerial modes of transport

What scale will advanced air mobility achieve in the next decade?

While air mobility enthusiasts project that over the coming decade (or soon after), an electric aircraft could become a popular mode of transportation and a viable alternative to traditional taxis, few players have so far managed to bridge the engineering-to-scale chasm, overcome product and business model uncertainties, or bend customer perception challenges related to noise and visual aesthetics

5 Sustainable and inclusive air mobility

When should customers expect affordable advanced air mobility solutions?

Novel, subscale modes of aerial transportation with a premium price tag may become available to customers in the next decade, but the industry may take significantly longer to scale and bend the cost of a short-haul flight to the equivalent of a taxi ride

Source: McKinsey analysis

Additional resources

Knowledge center

McKinsey Center for Future Mobility

Related reading

Mobility's second great inflection point

The future of mobility is at our doorstep

Advanced air mobility in 2030

Reimagining mobility: A CEO's guide

The zero-carbon car: Abating material emissions is next on the agenda