The Mobility of the Future



BEYOND THE ELECTRIC VS. NOT ELECTRIC DEBATE[1]

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"The humans call themselves homo sapiens to highlight their distinctive ability to anticipate the future and achieve their objectives with the most efficient means. And yet the technology that they use to move themselves, I wonder if they still deserve that name." - Visitor from Mars.

In 2025, Humans travelled about 64 trillion kilometres and two thirds of which is a four wheeled car.[2] There are 1.2 billion of these, one car for every six people and even more in some parts of the planet.[3] Yet these vehicles are not used for 95% of their usable life (indeed, occupy space called parking lots), only a fraction of their potential power is deployed (they normally run at 40 KPH although they are designed to go four times faster) and they use an energy (petrol or diesel) which costs three times more than the most efficient one (electricity).

Cars do have enormous merits. Invented one and a half centuries ago by two German engineers turned entrepreneurs (Daimler and Benz), they have been the cornerstone of the industrial society that enabled the most gigantic leap in wellbeing in history. They became the engine and symbol of a society (the American one) which managed to overcome its worst financial crisis (in 1929) by building the first mass consumer economy in the world (similar for Germany and Italy after the war), that enabled the most gigantic leap in human wellbeing.

Fossil-fuelled cars we have been using were not an unavoidable outcome of industrialisation. In 1902, Thomas Edison, famous for inventing and commercialising the lightbulb, opened a factory in New Jersey dedicated to the most promising technology[4]. a rechargeable electric battery vehicle that promised to replace the louder and more polluting internal combustion engine. That venture failed, and electric cars were outnumbered by fossil-fuelled ones and gradually forgotten in an increasingly industrialised society.

These observations highlight that the turnaround in mobility models is not just a question of "rational planning." A lot of "individual preferences" and chance also impact the evolution of how we transfer people and goods. Addressing these challenges requires not just a choice between electric cars and not electric ones: the debate which absorbs 90% of the words, the time policy makers and managers seem to dedicate to the question. We need to rethink the entire industrial systems, cities and social practices which shaped mobility and was shaped by it. The transition extends well beyond replacing fossil fuels with electricity, which dominates most of public and political debate. Equally transformative innovations could also reshape how we travel, how vehicles are used and how urban space is organised. This paper wants to be a pitch for developing a flexible roadmap towards a mobility system fit for the 21st century and the need to survive to the excesses of a model which became obsolete because of technologies and environmental emergencies.

2. Schäfer, A., *Long-Term Trends in Global Passenger Mobility*, National Academy of Engineering, Frontiers of Engineering, 2007; Schäfer, A., & Victor, D., *The Past and Future of Global Mobility*, Scientific American, 1997; OECD/International Transport Forum, *ITF Transport Outlook 2023*, 2023.

3. Rodrigue, J.-P., *Vehicle Use Indicators, World, 1950–2025*, The Geography of Transport Systems, accessed 28 September 2026.

4. As matter of fact, the Scottish inventor Robert Anderson is credited to have invented the first crude electric carriage between 1832 and 1839. The carriage was powered by non rechargeable primary power cells. U.S. Department of Energy, *The History of the Electric Car*, 2014.

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1 A brief history of mobility and looking for a method to navigate towards the future

Before diving into visionary ideas on how to fundamentally transform mobility, a brief look at where it came from is useful: understanding who travels, how, and why remains the foundation for designing mobility that actually fits the needs of the 21st century.

1.1 From walking to flying: Mobility's growing complexity.

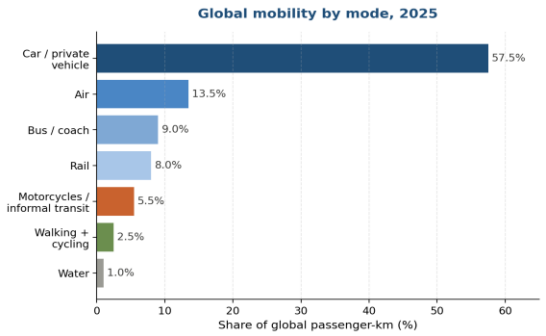
For most of human history, mobility was slow and simple. Walking and animal-drawn carriages dominated how people and goods moved, and the range of realistic options was narrow. The train, the bicycle, the car and the plane each broke that pattern in turn, each making a new kind of journey possible that had not existed before.[5] What these inventions added, was not a single better way to travel, but more ways each suited to a different kind of trip. A plane or a high-speed train makes sense over long distances where speed matters most. A car offers flexibility in areas poorly served by anything else. Within a dense city, a bike or a scooter can often out-perform both, door to door. Mobility became faster and more comfortable with each new mode, but also more complex: the right tool now depends on the journey, not on habit.

Despite this, the car remains the dominant mode in developed part of the world, carrying somewhere between 55 and 60 percent of the world's passenger-kilometres.[6] It is hard to believe that a single vehicle, built to carry four or five people at speed 160kmph over open roads, is genuinely the best tool for close to two-thirds of all the distance humanity travels much of which is short and urban, and better served, on nearly every measure, by transit, cycling or walking.

1.2 Who travels, how much, and where?

Globally, people travel roughly 64 trillion kilometres a year. Cars account for over half of that; air travel for around 13 to 14 percent, despite carrying a comparatively small, wealthy and frequent-flying share of the population; rail and bus split most of the rest; walking and cycling cover only 2 to 3 percent of total distance, even though they account for the largest share of individual trips people actually make.[7]

Exhibit 1. Global mobility by mode, 2025



Source: Schäfer and Victor (1997); ITF (2023); Vision estimate.[8]

5. Schäfer, A., *Long-Term Trends in Global Passenger Mobility*, National Academy of Engineering, Frontiers of Engineering, 2007; Schäfer, A., & Victor, D., *The Past and Future of Global Mobility*, Scientific American, 1997.

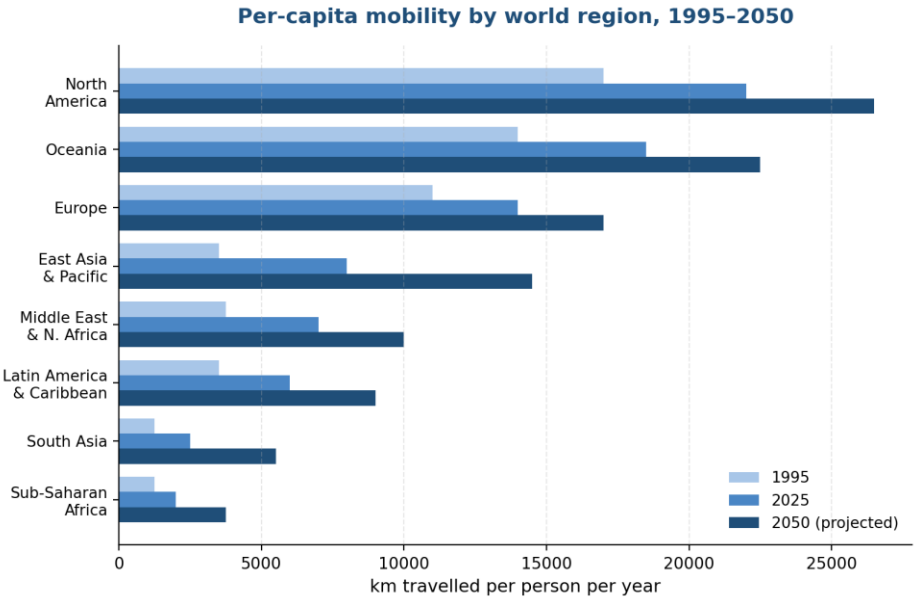
6. OECD/International Transport Forum, *ITF Transport Outlook 2023*, 2023; Schäfer, A., & Victor, D., *The Past and Future of Global Mobility*, Scientific American, 1997.

7. ICAO, *The World of Air Transport in 2024*, Annual Report 2024; Our World in Data, *Transport*, accessed 28 September 2026; IATA, *A Historically Resilient Industry*, 1 December 2022.

8. Schäfer, A., & Victor, D., *The Past and Future of Global Mobility*, Scientific American, 1997; OECD/International Transport Forum, *ITF Transport Outlook 2023*, 2023.

Travel differs across regions (Exhibit 2), a North American travels roughly 20,000 to 24,000 kilometres a year, overwhelmingly by car, European covers 13,000 to 15,000 kilometres, with meaningfully more of it by rail and bus. Someone in Sub-Saharan Africa travels under 2,500 kilometres a year, still largely on foot.[9]

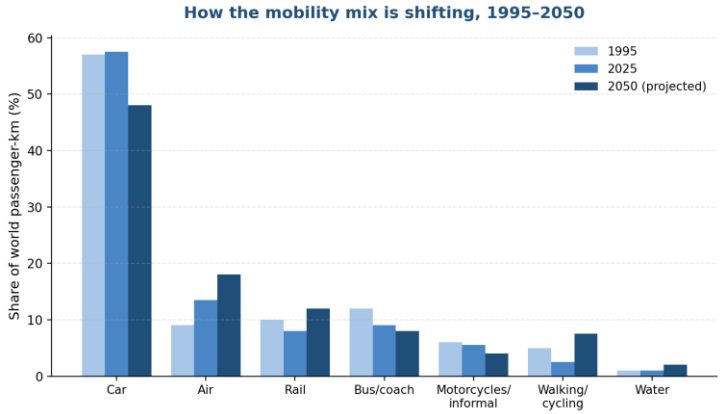
Exhibit 2. Per-capita mobility by world region, 1995–2050



Source: Schäfer and Victor (1997); ITF (2019, 2023); UN DESA (2024); Vision analysis.[10]

The projections indicate increasing distance travelled across all regions by 2050, with faster growth in developing economies than in developed countries.

Exhibit 3. Mode breakdown (share of world passenger-km)



Source: Schäfer (2007).[11]

9. Schäfer, A., *Long-Term Trends in Global Passenger Mobility*, National Academy of Engineering, Frontiers of Engineering, 2007; European Environment Agency, *Passenger transport activity*, Sustainability of Europe's Mobility Systems 2025, 2025; SLOCAT, *Africa regional overview*, Transport and Climate Change Global Status Report, accessed 28 September 2026.

10. Schäfer, A., & Victor, D., *The Past and Future of Global Mobility*, Scientific American, 1997; OECD/International Transport Forum, *ITF Transport Outlook 2023*, 2023; International Transport Forum, *Transport demand set to triple, but sector faces potential disruptions*, ITF Transport Outlook 2019 summary, 2019; UN DESA, *World Population Prospects 2024*, 2024; Ritchie, H., & Rodés-Guirao, L., *Peak global population and other key findings from the 2024 UN World Population Prospects*, Our World in Data, 2024.

11. Schäfer, A., *Long-Term Trends in Global Passenger Mobility*, in Frontiers of Engineering: Reports on Leading-Edge Engineering from the 2006 Symposium, National Academies Press, 2007.

The single biggest structural shift in 55-year span (Exhibit 3) is aviation and rail together ("high-speed modes" in Schäfer's terminology) roughly doubling their combined share, from ~18% in 1995 to ~31% by 2050 - mostly at the expense of car and bus share, even as car's absolute distance keeps rising.

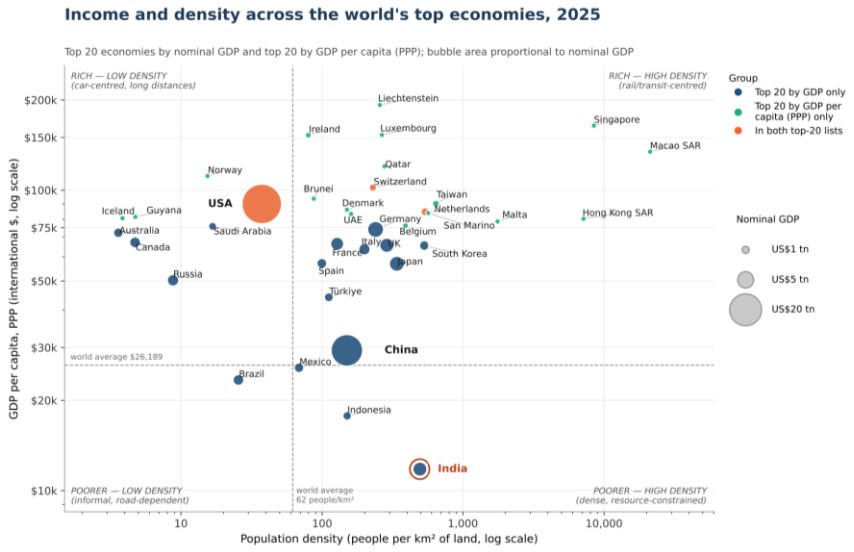
1.3 Is there an optimal mobility model? Pragmatic metrics between “rational planning” and “individual preferences”

Much of the unease about travel time rests on an assumption that is about to stop being true: that time spent moving is time subtracted from everything else. A commuter stuck behind the wheel cannot work, rest, or be present with family - the drive is pure cost, and more of it is close to unambiguously bad, for GDP, for health, for the environment. But a passenger in a self-driving car can answer email, join a call, or simply decompress; a traveller on a high-speed train with a proper desk and a power socket can work as productively as at their desk. The kilometre is the same. Its cost is not.

This does not resolve the old question of how many kilometers people “should” travel or how. But it changes what the answer is worth. A society that reclaims travel time rather than losing it, can afford a different relationship between mobility and wellbeing than one where every kilometer is dead time. That possibility strengthens the case for assessing the whole journey: whether people can reach what they need, how long it takes, what it costs, and which modes can serve it sustainably.

Where a country starts, shapes what is possible. Two measures, brought together, offer a starting point for assessing investment choices: income per person, adjusted for purchasing power, as a rough proxy for how much a government can tax and invest; and population density, as a rough proxy for how much of that investment can go into shared infrastructure rather than individual vehicles. Neither measure captures how people and destinations are distributed within a country. The matrix (Exhibit 4) is therefore a first screen; decisions about services and infrastructure require analysis at city and regional level.[12]

Exhibit 4. Income and density shape the mobility mix



Source: IMF World Economic Outlook (April 2026); World Bank; UN World Population Prospects (2024); Vision analysis.

Each quadrant points to different opportunities and constraints, rather than prescribing a single mix.. Rich, sparse countries like the United States, Canada and Australia rely on cars; Norway illustrates how

[12] IMF, World Economic Outlook (April 2026), GDP per capita, PPP, international dollars; World Bank / UN World Population Prospects (2024), population density, people per km². World average GDP per capita PPP: approximately $25,591 (IMF, 2026). World average population density: approximately sixty-three people per km² (UN, 2024).

fleet electrification can be one response where cars remain important. Rich, dense Japan, Switzerland, the Netherlands and Singapore built rail, transit and cycling around concentrated demand. Dense, lower-income India and Indonesia move people by bus, rail and two-wheelers, while cities in Brazil and Mexico show how bus rapid transit can serve particular urban corridors. Resource-rich Russia and Gulf states show income alone does not predict investment. The choice of modes must also reflect urban form, existing networks, affordability and the journeys people need to make.

BCG's City Mobility Compass reinforces the need for local comparison. It groups 150 cities into six archetypes based on characteristics including size, density, layout and transport systems; mobility outcomes differ substantially between those groups. Cities can learn more from peers with comparable conditions than from an absolute ranking. The pace of change matters too: BCG reports that 95% of surveyed cities have 2035 modal-shift targets, yet they are 10-15 percentage points behind the trajectory needed to meet them. Historically, most cities have shifted modal share by only three to five percentage points per decade.[13] A credible mobility mix must therefore include a feasible path from today's network to the intended one.

What is the right mobility mix?

There is no universal optimal distance per person. Success should be judged by accessibility, how easily people reach jobs, services and social opportunities, not by kilometres travelled or money spent; travel also has intrinsic value through leisure and freedom. The right model depends on people and purposes, place, and system capacity (IPCC, 2022), so income and density are starting points, not prescriptions, and urban rather than national density should be used where possible. Depending on local conditions, the mix may combine shorter journeys, walking and cycling, public transport, shared services and cleaner vehicles in different proportions. Western Europe and Japan offer useful examples, but their travel distances are observations, not targets for other places. Both the need to travel and the way journeys are made matter. Outcomes should be tested across income, age, disability and location.

1.4 The right tool for the right journey

The question worth asking, is not just how many kilometres people should travel, but whether we have the right tool for the right mobility need. A well-functioning mobility system matches mode to journey: speed and reliability for long distances, flexibility for rural and dispersed areas, low-footprint options for dense cities. Getting that match right is what allows an economy to function: moving people and goods to where they are needed, without wasting time, money, or capacity on the wrong tool for the job.[14]

Mobility also needs to be sustainable. That means less air pollution and fewer of the fine particulates that damage lungs, lower emissions, less noise, and fewer traffic deaths - not as an afterthought, but as part of what "working well" means.[15] Ultimately, mobility should get people and goods from one place to another in the way they actually want: a mix of speed, convenience, comfort, price, safety, sustainability and adaptability, including for the elderly, the disabled, and anyone without access to a car.

13 Hagenmaier, M., et al., "*The Global Champions of Urban Mobility*," Boston Consulting Group, 7 January 2026.
14. Asher, S., & Novosad, P., *Rural Roads and Local Economic Development*, American Economic Review, 2020.
15. ITF/OECD, *Road Safety Annual Report 2024*, 2024; Big Think, *U.S. road deaths far outnumber those in Europe. Why?*, accessed 28 September 2026. WHO Regional Office for Europe, *Transport, Health and Environment*, 29 June 2023.

2 From Car Dependence to Integrated Mobility

2.1 Redefining Success: Accessibility, Efficiency and Quality of Life

Success in mobility has been traditionally measured by proxies that describe the vehicle rather than the traveller: top speed, horsepower, how many cars a country owns per capita. None of these say whether people can get to the things they need. Three criteria do a better job, and this paper judges every innovation described in it against them.

Accessibility and user satisfaction ask whether people can reach jobs, healthcare, education, family and leisure opportunities, and how they experience those journeys. A dense, well-connected neighbourhood can offer better access through a ten-minute walk than a dispersed settlement offers through a forty-minute drive. But mobility should also provide comfort, autonomy and enjoyment, giving people meaningful choices about how they travel.

Efficiency and affordability ask how effectively a mobility system uses scarce resources and whether people can afford the access it provides. Relevant measures include door-to-door travel time and reliability, household transport expenditure as a share of income, and the energy and space required per passenger. A vehicle's speed says little about its usefulness if journeys are unpredictable, ownership is costly or it spends most of its time parked. An effective system makes dependable journeys affordable while using time, energy, space, and capital efficiently across the whole network.

Quality of life asks how mobility affects people's health, their surroundings, and the environment. Its performance should be evaluated through deaths and serious injuries, opportunities for physical activity, exposure to air pollution and noise, and lifecycle greenhouse-gas emissions, measured both in total and per passenger-kilometre. Assessment must also consider how benefits and burdens differ across income groups, ages, abilities, and locations. A system that provides convenient journeys for some while excluding others or imposing substantial health and environmental costs cannot be considered successful.[16]

2.2 Three Dimensions of Change: Technology, Ownership and Systems

Delivering on accessibility, efficiency, and quality of life at the same time requires change along three separate dimensions, and the rest of this paper is organised around them.

Much of the public debate about the future of mobility has narrowed to a single question: electric cars or not. That debate matters, but it is a fraction of what is actually changing. Some of what follows is genuinely visionary - vehicles that use the empty airspace above cities, cars that drive themselves. Some of them are almost old-fashioned, yet no less transformative - the humble train, reinvented as high-speed rail, and roads intelligent enough to tell the cars on them how to move. Treating electrification as the whole story misses most of the actual revolution.

Technology (Chapter 3) expands what is physically possible: vehicles that can use the empty airspace above cities, drive themselves, run on more efficient fuels rather than fossil fuel. Technology on its own, however, only ever creates an option - it does not decide who gets to use it, or how.

Ownership and service models (Chapter 4) decide how access to that technology is actually organised: whether a vehicle is privately owned and idle most of the day or shared and in near-constant use; whether public transport is treated as the backbone of a city or as a residual option; how the first and last kilometre

16. Stutzer, A., & Frey, B. S., *Stress that Doesn't Pay: The Commuting Paradox*, Scandinavian Journal of Economics, 2008; linked working paper: IZA Discussion Paper No. 1278, 2004. WHO Regional Office for Europe, *Transport, Health and Environment*, 29 June 2023.

of a journey, often the hardest part to solve, gets covered. The same underlying technology can deliver vastly different accessibility and efficiency outcomes depending on the ownership model around it.

System integration (Chapter 5) is what makes the first two dimensions add up to more than the sum of their parts: the infrastructure, managing the demand, data standards and regulation that let different modes and providers work together rather than as isolated islands, and the legacy investments, habits and vested interests that slow all of the above down. A city can have the right technology and the right ownership models can still fail its residents if a single trip requires multiple apps, incompatible ticketing, and infrastructure built for a different century.

3 Technology: Expanding How People and Goods Move

Chapter 1 argued that the true cost of a kilometer travelled is changing, not because people are moving differently, but because the time and space a journey consumes are being reclaimed. This chapter looks at the technologies making that possible directly: aircraft that use space above cities that nothing else claims, vehicles that no longer need a human's full attention, and propulsion that waste less energy per kilometer than anything that came before it.

3.1 Low-Altitude Mobility

The next dimension of urban mobility may be vertical. Low-altitude mobility is relevant where conventional ground transport is disproportionately slow: congested and constrained by water or terrain or Infrastructure. Electric vertical take-off and landing aircraft (eVTOLs), or "flying cars", can bypass road congestion, circuitous networks and geographical barriers, creating near point-to-point connections, with potentially substantial time savings. A 100-km aerial journey taking approximately 27 minutes, compared with 154 minutes by car an 83% reduction.[17] However, this advantage should be evaluated on a door-to-door basis, since access to vertiports, waiting, boarding and onward ground travel add time.[18]

The environmental advantage is also conditional. VTOLs perform poorly against ground vehicles on shorter trips, with the energy-intensive take-off and landing phases making them less favourable up to approximately 35 km. At 100 km, a single-occupant VTOL generated 28% more greenhouse-gas emissions than a battery-electric car. However, with three passengers and a pilot, its emissions per passenger-kilometre were 52% lower than a combustion-engine car and 6% lower than an electric car, assuming 1.54 occupants in the ground vehicles. Thus, occupancy is a decisive variable: the sustainability case depends on shared, high-utilisation operations rather than simply electrifying flight or inherent environmental advantage of flight.[19]

The economic opportunity is developing alongside technology. McKinsey estimates that air taxis could represent a several-billion-dollar market by 2030, potentially reaching tens of billions of dollars globally in the early 2030s, although these estimates depend on successful certification, infrastructure deployment, affordability and consumer adoption.[20] China is pursuing a broader low-altitude-economy strategy, with the sector projected to exceed RMB 3.5 trillion by 2035; this figure includes drones and other low-altitude activities not just passenger-air-taxi revenue.[21]

17. Kasliwal, A., et al., *Role of flying cars in sustainable mobility*, Nature Communications, 10, 1555, 2019.

18. Federal Aviation Administration, *Engineering Brief No. 105A: Vertiport Design*, 2024.

19. Kasliwal, A., et al., *Role of flying cars in sustainable mobility*, Nature Communications, 10, 1555, 2019.

20. McKinsey & Company, *Advanced air mobility in 2030*, 19 November 2021, "A multibillion-dollar market".

21. Xinhua, *China's burgeoning low-altitude economy empowers industries via diverse applications*, State Council of the People's Republic of China, 17 October 2025.

Commercialisation is progressing through restricted applications. In March 2025, two EHang EH216-S operators received Chinese operating certificates permitting paid pilotless flights. Initial approvals focused on sightseeing and flight experiences returning to their departure point.[22,23]

Airships could expand the low-altitude economy through energy-efficient freight services and connections to regions with limited transport infrastructure. Research identifies a potential niche between air and maritime transport, particularly for remote communities and specialised cargo[24], this development can potentially revolutionize goods transport.

The role of low altitude mobility depends on infrastructure, safety, airspace management, autonomy, noise and public acceptance. EASA's 2021 survey found 83% of respondents initially positive towards urban air mobility, but only 49% ready to try an air taxi, with safety, noise and environmental impacts among the concerns.[25] Deployment should be judged against occupancy, empty repositioning, lifecycle emissions, affordability and the transport modes displaced and on how effectively aerial services integrate with the wider transport system.

3.2 Autonomous Vehicles

Autonomous vehicles could reshape mobility by enabling transport on demand, expanding access for people unable to drive and allowing passengers to use journey time for other activities. Their strongest immediate promise is safety: road crashes kill approximately 1.16 million people annually, making safer driving a major public-policy priority.[26]

Commercial deployment is already visible in California, where Waymo operates in the San Francisco Bay Area and Los Angeles. Across its operating markets, the company reports more than 500,000 autonomous electric trips weekly.[27] Its safety analysis, covering 271.3 million driverless miles through June 2026, reports 82% fewer injury-causing crashes and 95% fewer crashes involving serious injury or death than geographically adjusted human-driving benchmarks. These findings demonstrate substantial potential, although they describe one operator’s performance within specific operating conditions.[28]

Automation could also release time previously spent driving. Illustratively, 500,000 weekly journeys averaging an assumed 17 minutes represent approximately 142,000 hours of driving time potentially freed each week, if each replaces a personally driven journey. However, today’s systems offer different capabilities. Level 2 requires continuous driver supervision; Level 3 permits automated driving with a human available to take over; Level 4 removes that requirement within defined operating conditions. Commercial robotaxis demonstrate this bounded autonomy, while Level 5 operation across all roads and conditions remains unavailable.[29]

The economic opportunity extends across vehicle technology and mobility services. McKinsey’s 2023 analysis projects $300–400 billion in passenger-car revenues by 2035 from advanced driver-assistance and autonomous-driving systems combined. This is a conditional market forecast, rather than an estimate of economy-wide benefits or robotaxi revenues alone.[30]

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22. Low Altitude Economy, *Global 2026 Outlook: The Year the Low-Altitude Economy Gets Real*, 2026.

23. EHang, *EHang EH216-S Interpretation Series: Air Operator Certificate*, 2025.

24. Prentice, B. E., Phillips, A., Beilock, R. P., & Thomson, J., *The Rebirth of Airships*, Journal of the Transportation Research Forum, 44(1), 173–190, 2005.

25. European Union Aviation Safety Agency, *Urban Air Mobility: 10 Key Survey Results*, 2021.

26. World Health Organization, *Road traffic injuries*, accessed 28 September 2026.

27. Waymo / Alphabet, *Sustainability at Waymo*, weekly autonomous electric-trip disclosure, 2026; accessed 28 September 2026.

28. Waymo, *Safety Impact*, data through June 2026.

29. National Highway Traffic Safety Administration, *Automated Vehicle Safety*, accessed 28 September 2026.

30. Deichmann, J., et al., *Autonomous driving’s future: Convenient and connected*, McKinsey & Company, 6 January 2023.

Adoption nevertheless requires substantial investment in technology and validation, public confidence, regulatory coordination, cybersecurity and clear liability arrangements.[31,32] The challenge for autonomous mobility is increasingly one of deployment economics. A viable robotaxi service needs local safety approval, validated routes, fleet operations, charging, maintenance, insurance, booking platforms and public trust. BCG projects a global fleet of 700,000 to 3 million robotaxis by 2035, but expansion is likely to be gradual: even in San Francisco and Beijing, they account for less than 1% of taxi and ride-hailing fleets. Their role will depend on whether operators can provide reliable service at a sustainable cost in each city. Robotaxis and autonomous shuttles may offer particular value by connecting passengers to public transport and serving areas where frequent fixed-route services are difficult to provide.[33]

Environmental gains also require scrutiny: Waymo's electric fleet eliminates tailpipe emissions, but this alone does not establish the climate benefits of automation.[34] Cities should therefore make deployment conditional on measurable outcomes: fewer injuries, accessible services, high occupancy and lower lifecycle emissions and substitution away from public transport. Integrating autonomous fleets with public transport and electrification offers a credible direction for future mobility, if performance is assessed across the whole transport system.

3.3 Electrification and Energy Efficiency

The energy powering future mobility will increasingly be electricity, supported by other low-carbon options where direct electrification is difficult. Battery-electric vehicles (BEVs) offer lower energy consumption, cleaner urban air and reduced oil dependence. ICCT estimates that BEVs sold in the European Union in 2025 generate 73% fewer lifetime greenhouse-gas emissions than petrol cars, including vehicle and battery production.[35]

Adoption is accelerating (Exhibit 5). Global electric-car sales exceeded 20 million in 2025, representing 25% of new-car sales; these figures include BEVs and plug-in hybrids. The IEA forecasts 23 million sales and a 28% share in 2026. Regional differences remain substantial: electric cars accounted for nearly 55% of sales in China, 28% in Europe and just under 10% in the United States in 2025. Different starting prices, policy incentives, charging access and model availability help explain why these markets have no common adoption curve.[36]

The local economic case depends on purchase price, financing, energy prices, mileage and the possibility of convenient charging. For cars charged at home, the IEA estimates annual energy-cost savings over petrol vehicles of approximately US$860 in the United States and US$500 in the United Kingdom in 2025.[37] In China, nearly 70% of BEVs sold were already cheaper than comparable combustion vehicles before incentives.[38] Nevertheless, lower running costs do not always offset higher purchase prices quickly; CSEP's Indian analysis finds that private electric cars will likely need tax support until at least 2030.

Policy support and industrial competition are driving this transition. Tighter EU vehicle-emissions standards supported a 30% increase in European electric-car sales in 2025, while Chinese tax relief and vehicle-replacement incentives sustained demand.[39] Globally, public charging points exceeded seven

31. National Highway Traffic Safety Administration, *Automated Vehicle Safety*, accessed 28 September 2026.

32. Deichmann, J., et al., *Autonomous driving's future: Convenient and connected*, McKinsey & Company, 6 January 2023.

33 Hagenmaier, M., et al., *"Here at Last: The Evolution of the Robotaxi*," Boston Consulting Group, 2026.

34. Waymo / Alphabet, *Sustainability at Waymo*, weekly autonomous electric-trip disclosure, 2026; accessed 28 September 2026.

35. Negri, M., & Bieker, G., *Life-cycle greenhouse gas emissions from passenger cars in the European Union: A 2025 update and key factors to consider*, International Council on Clean Transportation, 2025.

36. International Energy Agency, *Global EV Outlook 2026: Executive summary*, 2026.

37. International Energy Agency, *Global EV Outlook 2026: Electric vehicle charging*, 2026.

38. International Energy Agency, *Global EV Outlook 2026: Trends in electric cars*, 2026.

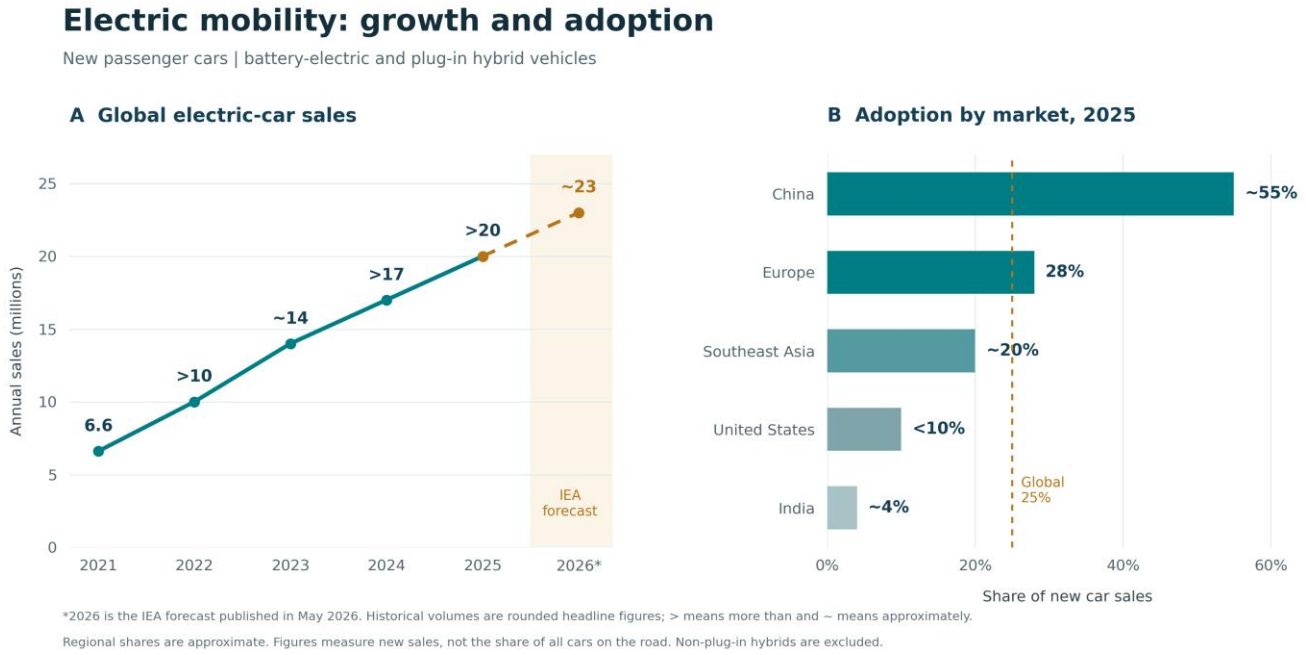
39. International Energy Agency, *Global EV Outlook 2026: Trends in electric cars*, 2026.

million.[40] Cheaper batteries and growing model choice are broadening access.[41] Continued progress requires affordable financing, reliable charging and electricity networks that expand with demand, supported by cleaner power generation and effective battery recycling.[42] The transition will unfold differently across countries as costs, energy prices, infrastructure, policies and consumer needs vary. EVs can improve the environmental performance of many journeys, but the right mobility mix also depends on reducing unnecessary travel and choosing the most effective mode for each local context.

Hydrogen has a more selective role, particularly in some bus and heavy-truck operations where rapid refuelling and demanding schedules matter. Fuel-cell vehicles emit no exhaust CO_2, but their climate performance depends on production: for EU passenger cars, ICCT estimates lifetime emissions 79% below petrol cars with renewable hydrogen, compared with 26% below when hydrogen comes from natural gas.[43] High fuel costs, scarce refuelling infrastructure and lower overall energy efficiency than BEVs constrain wider adoption.[44]

More efficient internal combustion engines (ICEs) and hybrids can reduce fuel consumption during the transition where charging remains inadequate. However, their emissions reductions are smaller: ICCT's EU comparison estimates approximately 20% for conventional hybrids and 30% for plug-in hybrids compared with petrol cars and can be a viable short-term option[45].

Exhibit 5. Electric mobility growth and adoption



Figures include BEVs and plug-in hybrids. Historical sales are rounded; 2026 is a forecast.

Source: IEA (2022); IEA (2023); IEA (2024); IEA (2025); IEA (2026b).[46]

40. International Energy Agency, *Global EV Outlook 2026: Electric vehicle charging*, 2026.

41. BloombergNEF, *Lithium-Ion Battery Price Survey*, December 2025; public results announcement, 9 December 2025.

42. Zaino, R., Ahmed, V., Alhammadi, A. M., & Alghoush, M., *Electric Vehicle Adoption: A Comprehensive Systematic Review of Technological, Environmental, Organizational and Policy Impacts*, World Electric Vehicle Journal, 15(8), 375, 2024.

43. Negri, M., & Bieker, G., *Life-cycle greenhouse gas emissions from passenger cars in the European Union: A 2025 update and key factors to consider*, International Council on Clean Transportation, 2025.

44. EIT Urban Mobility, *The Role of Hydrogen in Urban Mobility*, 2024.

45. Negri, M., & Bieker, G., *Life-cycle greenhouse gas emissions from passenger cars in the European Union: A 2025 update and key factors to consider*, International Council on Clean Transportation, 2025.

46. IEA, *Global EV Outlook 2022: Trends in electric light-duty vehicles*, 2022; IEA, *Global EV Outlook 2023: Trends in electric light-duty vehicles*, 2023; IEA, *Global EV Outlook 2024: Trends in electric cars*, 2024; IEA, *Global EV Outlook 2025: Executive summary*, 2025; IEA, *Global EV Outlook 2026: Executive summary*, 2026.

4 Ownership and Service Models: Rethinking Access to Mobility

The previous chapter's technologies only reduce the cost of travel if they reach the people who need them. This chapter is about that second, less visible cost: the vehicle itself, sitting idle, owned outright when it could be shared. Getting the ownership model right can matter as much as the technology underneath it.

4.1 Shared Mobility: Matching Vehicles to Journey Needs

Shared mobility could reshape future transport by making access to the right vehicle more attractive than ownership. Private cars remain parked for approximately 95% of the time, highlighting the opportunity to improve asset utilisation.[47] A diversified network can match shared bicycles and e-scooters to short journeys, cars to occasional family trips, and pooled shuttles to connections with public transport.

The opportunity extends beyond operating vehicles. Station-based and free-floating fleets generate revenue through usage charges and memberships, while peer-to-peer platforms connect vehicle owners with renters and retain transaction commissions.[48] Mobility as a Service (MaaS) combines journey planning, booking and payment for buses, trains, shared cars and micromobility in one interface. Pay-as-you-go fares, subscriptions and employer-funded mobility budgets can make these services a practical alternative to maintaining a private car.[49] Manufacturers can participate through fleet supply and servicing, while employers can offer flexible mobility.

Evidence indicates that sharing can reduce vehicle ownership. In a study of 35 German cities, it was found that each additional station-based shared car was associated with approximately nine fewer privately owned cars.[50] Lower parking demand creates opportunities to convert street space into cycle lanes, greenery and public amenities.

Digital platforms can coordinate demand, vehicle availability and connections, including demand-responsive services in areas with limited public transport. Autonomous fleets could further reduce driver costs and reposition vehicles between trips for shared mobility, although managing peak-hour demand also requires pooling and coordination with mass transit.[51] McKinsey's 2023 scenarios projected $500 billion - $1 trillion in annual shared-mobility spending by 2030, depending on adoption, regulation and technological progress.[52]

Adoption depends on dependable availability, competitive prices and safety. The desire for personal space can also make passengers reluctant to share rides. Services must earn users' confidence that suitable transport will be available for both routine and unexpected journeys. Its contribution to

47. McKinsey & Company, *Shared mobility: Sustainable cities, shared destinies*, 2023.

48. Stocker, A., & Shaheen, S., *Shared Automated Vehicles: Review of Business Models*, International Transport Forum Discussion Papers, 2017/09, OECD Publishing, 2017.

49. International Transport Forum, *Integrating Public Transport into Mobility as a Service: Summary and Conclusions*, ITF Roundtable Reports, 184, OECD Publishing, 2021.

50. Kolleck, A., *Does car-sharing reduce car ownership? Empirical evidence from Germany*, Sustainability, 13(13), 7384, 2021.

51. Stocker, A., & Shaheen, S., *Shared Automated Vehicles: Review of Business Models*, International Transport Forum Discussion Papers, 2017/09, OECD Publishing, 2017; International Transport Forum, *Integrating Public Transport into Mobility as a Service: Summary and Conclusions*, ITF Roundtable Reports, 184, OECD Publishing, 2021.

52. McKinsey & Company, *Shared mobility: Sustainable cities, shared destinies*, 2023.

sustainable mobility will depend on increasing occupancy, electrifying fleets, while supporting walking, cycling and public transport.[53]

4.2 Train Innovations & Public Transport (Rail, Buses, Trams and Ferries)

Rail is the most energy-efficient mode per passenger-km of any large-scale transportation system, yet service has historically stopped at national borders and withered, on both day and night routes, against cheap short-haul flights. It retains the capacity to move large numbers of passengers both within and between cities, if on renewable power, this can be one of the most sustainable modes available.[54]

Key innovations can make trains a more attractive means of transportation again. A cross-border high-speed and night-rail network, with carriages reconfigured around desks and power outlets so travel time can be productive. This directly reduces demand on the shared fleets of Chapter 4.1 and on short-haul flights. The evidence that rail can actually take this share from aviation is not projection but history: when high-speed rail opened on Spain's Madrid–Seville route in the early 1990s, the airline's share of that market fell from 40% to 13% within a few years, while rail's share rose from 16% to 51%.[55] More recent research finds that a good night-train connection on its own can potentially shift 10% to over 30% of a route's air passengers onto rail.[56] For longer trips, new or relaunched routes such as a direct link between Paris and Berlin, Amsterdam and Milan, or Munich and Rome are crucial,[57] and expanding these connections is realistic wherever regulation can be coordinated across a large area like Europe, but also the USA, Canada, China or India. In these countries one train route could directly connect Copenhagen with Madrid, or Boston with Washington DC.

New battery systems are also making rail viable on routes that currently run on fossil fuels: electric trains can charge from overhead power lines wherever those are easy to build, then run for hours on battery power across the unelectrified sections in between, saving the cost of full electrification while still making the route sustainable. [58]

Self-driving trains are currently being developed by various companies such as Siemens Mobility alongside Deutsche Bahn[59] these systems could further reduce the cost of transportation.

Expansion also faces practical constraints: signalling interoperability, track-gauge differences on some corridors, rolling-stock availability, capacity, and ticketing arrangements. In densely built areas, acquiring space for additional tracks can be difficult, while tunnelling or elevated construction can be costly. Rail rarely provides a complete door-to-door journey; buses, trams, ferries, and shared vehicles can provide complementary connections and cover the last mile connectivity problem.

53. Stocker, A., & Shaheen, S., *Shared Automated Vehicles: Review of Business Models*, International Transport Forum Discussion Papers, 2017/09, OECD Publishing, 2017; International Transport Forum, *Integrating Public Transport into Mobility as a Service: Summary and Conclusions*, ITF Roundtable Reports, 184, OECD Publishing, 2021.

54. IEA, *The Future of Rail*, 2019.

55. Haas, P. J., *Modal Shift and High-Speed Rail: A Review of the Current Literature*, Mineta Transportation Institute, Report 12-35, 2014. Oesingmann, K., & Ennen, D., *The impacts of high-speed rail expansion on short-haul air passenger transport – Evidence from German domestic and international traffic*, Case Studies on Transport Policy, 21, 101549, 2025.

56. Curtale, R., Larsson, J., & Nässén, J., *Understanding preferences for night trains and their potential to replace flights in Europe. The case of Sweden*, Tourism Management Perspectives, 47, 101115, 2023.

57. Back-on-Track, *Night Train Map 2026*, 2026; European Sleeper, *European night-train routes*, 2026; Voyspark, *Interrail and Eurail Pass 2026: Complete Guide to Passes, Routes and Hacks for Crossing Europe by Train*, 2026.

58. Siemens Mobility, *Mireo Plus decarbonises Europe's railways*, accessed 28 September 2026.

59. Siemens Mobility, *AutomatedTrain showcases the future of driverless rail travel*, accessed 28 September 2026.

5 System Integration: Making mobility work as a whole.

None of the preceding chapters deliver on their own. A self-driving car stuck in unpredictable traffic does not give anyone their time back; a shared vehicle nobody can find through a single app does not get used. This chapter is about the difference between a collection of good ideas and a mobility system: the infrastructure, rules and institutional habits that decide whether the savings promised in Chapters 3 and 4 become real.

5.1 Intelligent Infrastructure

Today's roads are largely “dumb”: traffic lights run on fixed timers regardless of actual traffic, and a single trip spanning a shared bike, a metro, a self-driving car and eventually a low-altitude drone requires a different app and a different ticket for each leg.

Vehicle-to-everything (V2X) communication lets roads, signals and vehicles exchange real-time data. This makes adjusting traffic-light timing to actual flows possible, giving trams priority at junctions, and warning vehicles of hazards. Sensors in the roads can track not only intelligent vehicles like modern cars but even bikes to turn traffic lights on and off when necessary.[60] At the same time, integrated mobility platforms can plan, book, and pay for an entire multimodal journey door to door. This is the connective tissue binding together every other chapter in this paper: self-driving cars, shared fleets, trains, and low-altitude drones only function as one coherent system if the infrastructure and software beneath them can talk to each other.

Evidence from intelligent traffic systems includes measured corridor outcomes and modelled city-scale scenarios. A US Department of Transportation before-and-after study across eight Florida corridors found an average travel-time reduction of 9.36%,[61] and a 2025 study across China’s hundred most congested cities found adaptive control cut peak-hour trip times by 11%, saving an estimated 31.7 million tonnes of CO2 a year at national scale in the modelled scenario.[62] Smaller local deployments echo this: Manchester is rolling out a £30 million AI-driven adaptive traffic-signal network, and Darmstadt’s V2X-based “Signal2X” system already tells drivers and cyclists the exact speed needed to catch a continuous green wave across the city.[63] At the same time, apps already integrate public transport with bike sharing, though these offers remain limited. The goal would be to buy one ticket when travelling from Rome to Munich door to door, with the platform calculating which combination of modes is fastest and best fits the passenger’s needs. That may mean to find the cheapest one, or avoiding bike sharing for non-cyclists, or car sharing for people without a driver’s licence. It is this integrated system that will make the backbone of the mobility of the future.

Key challenges to intelligent cities are that communication networks between infrastructure and vehicles, as well as city-wide roadside sensors and 5G-linked signal controllers, remain expensive to install. Today’s pilots remain isolated islands rather than an interoperable national or European standard. These systems also require multiple fail-safes and redundancies, so that if an intelligent traffic-light system fails, traffic can continue safely rather than a junction showing red, or worse green, in every direction at once. Another challenge is the communication standard itself: 5G is fast but not yet fully reliable everywhere, while the GSM-R standard used on most of today’s rail network is far more robust but was never built for

60. Intellias, *How do smart traffic lights work? Technology overview*, accessed 28 September 2026.

61. U.S. Department of Transportation, ITS Joint Program Office, *Implementation of Adaptive Signal Control Technology in Florida Resulted in an Overall Travel Time Reduction of 9.36 Percent for Eight Corridors*, 2021.

62. Wu, K., et al., *Big-data empowered traffic signal control could reduce urban carbon emission*, Nature Communications, 2025.

63. Yunex Traffic, *Signal2X: Green Waves for clean Air*, Darmstadt deployment, accessed 28 September 2026.

the volume of vehicle-to-everything traffic a fully connected city would generate. Standardizing across these systems will be important but requires regulation across borders.

5.2 Managing Demand in mobility

Better mobility also means fewer and shorter journeys to reach the same opportunities. Technology can help cities manage mobility more effectively. Real-time information, integrated ticketing and responsive services and AI can make existing networks easier to use. In many cities, homes, jobs and services are separated, making long commutes and car dependence a consequence of urban form. Demand management belongs alongside vehicles, services and intelligent infrastructure: it changes how much travel is necessary before transport mode is chosen.

Polycentric, mixed-use neighbourhoods bring work, schools, healthcare and shops closer to homes. Safe walking and cycling routes make local trips practical, while frequent public transport links neighbourhood centres and preserves access to opportunities across the city. The 15-minute-city approach expresses this principle, but it is a planning objective rather than a uniform template: distances, geography, housing costs and the availability of services differ between places. BCG estimates that, where this approach is fully realised, travel needs could fall by 15–20%.[64] That is a potential outcome, not a forecast for every city. The IPCC finds that compact, mixed-use development and accessible public transport can reduce vehicle travel and emissions.[65] Implementation should therefore combine land-use decisions with transport investment, especially where new housing and jobs are planned. Cities should measure the time and cost of reaching essential destinations across income groups and neighbourhoods, alongside changes in trip length and emissions. Shorter journeys count as progress only when residents retain, or gain, access to work, care and services.

5.3 Innovation-triggering regulations

Putting a new class of vehicle on the road or in the air means accepting a genuine risk to public safety. New autonomous systems can, quite literally, run someone over, so regulators are naturally cautious, even though excessive caution can freeze an entire industry before it starts. In addition, these innovations also depend on costly new public infrastructure that only a regulator can mandate or fund.

Three different answers are now being evaluated in parallel: the European Union treats autonomous systems as “high-risk,” requiring proof of safety before market entry;[66] the United States lets manufacturers self-certify and regulates after the fact; China runs fast, centrally coordinated certification pathways. This single choice of regulatory philosophy is arguably the biggest reason some of the innovations described in this paper are already commercial in one region and still experimental in another: China certified a commercial eVTOL aircraft in roughly 31 months, against a comparable Western process that typically takes 5–7 years,[67] and has approved robotaxi operations in more than 30 cities, while the EU’s own unified framework is under progress. Faster regulation is not free, however: Europe’s new Product Liability Directive, extending strict liability to software and AI failures, shows that the trade-off between speed and accountability must be made explicit rather than left ambiguous.[68] The advantage for regions moving more slowly is the ability to leapfrog other countries’ experience rather than repeat

64 BCG, The Global Champions of Urban Mobility, 2026. *bcg.com/publications/2026/the-global-champions-of-urban-mobility*

65 IPCC, *Climate Change 2022: Mitigation of Climate Change*, Working Group III, Chapter 8, “Urban Systems and Other Settlements,” 2022. ipcc.ch

66. European Parliament, *EU AI Act: first regulation on artificial intelligence*, accessed 28 September 2026. European Commission, *Commission Implementing Regulation (EU) 2022/1426*, 5 August 2022, type-approval of automated driving systems.

67. Low Altitude Economy, *How China Certifies eVTOL in 31 Months While Western Competitors Chase 7-Year Timelines*, 2025.

68. Reed Smith, *The new EU Product Liability Directive: key implications for automotive and autonomous vehicle companies*, 2025. European Parliament and Council, *Directive (EU) 2024/2853 on liability for defective products*, 23 October 2024.

their trial and error. This is also why the fastest-moving innovations tend to cluster wherever the underlying need is most acute, such as low-altitude mobility in China's densest megacities.

For regions currently falling behind, such as Europe, the more effective use of regulation is often to adopt rather than reinvent: if companies elsewhere can already deliver self-driving cabs, it may be more efficient to license or adapt than to develop a competing one from scratch. Europe's dense, historic city centres, its large existing rail network, and its shorter distances between major cities all favour investment in rail and multimodal integration over solutions built for sprawling, car-dependent geographies. International agreement on common standards for self-driving vehicles would also boost adoption across borders. Finally, subsidies and infrastructure built around legacy, petrol-fuelled mobility need to be phased-out in step with support for the innovations described in this paper, or the incentives will keep pointing in opposite directions. Governments should adopt technology-neutral regulation that rewards measurable improvements in mobility. Battery-electric vehicles, hydrogen-powered transport, autonomous systems, aerial mobility, and other emerging solutions should be assessed against common objectives for safety, lifecycle emissions, efficiency, affordability, accessibility, interoperability, and resilience. Regulation should also internalise environmental and social externalities through mechanisms such as carbon pricing and the "polluter pays" principle. Consistent with this paper's framework, these rules should incentivise companies to address specific transport needs with solutions that are fast, safe, affordable, and efficient. Each innovation should serve the journeys for which it is best suited and connect seamlessly with other modes, contributing to the performance of the wider mobility system.

Regulation should address the mobility system, requiring interoperability between new mobility services, public transport, infrastructure, and digital platforms. Governments should use common mobility indicators and real-world data to monitor performance and continuously adapt regulation as technologies evolve. This approach allows different technologies to compete while ensuring that innovation contributes to a safer, cleaner, more connected, and efficient mobility system.

5.4 Managing Legacies

The transition to future mobility is constrained not only by technology but also by the legacy of existing infrastructure, investments, regulations and consumer behaviour. Decades of investment in roads, parking, fuelling networks, vehicles and car-centric urban planning create significant infrastructural and institutional lock-in, fuel-tax revenue, reinforced by the emotional attachment to private ownership described in Chapter 4.1[69] and by public misinformation about how safe and capable new technologies are. These assets cannot simply be abandoned; instead, the transition should progressively repurpose, upgrade or retire legacy systems while developing new mobility infrastructure.

Managing this transition also requires addressing its economic and social costs. Governments should provide predictable pathways through targeted incentives, infrastructure investment, carbon pricing and fleet-renewal mechanisms, while ensuring that transition costs are distributed fairly. Existing roads, parking spaces, fuel stations and energy networks should be treated as adaptable assets - for example, through conversion to charging, shared mobility, logistics or public transport infrastructure. The objective is not to eliminate legacy systems immediately, but to maximise their residual value while redirecting investment towards a safer, cleaner, more connected and efficient mobility system in a way where the new technologies do not just have to be cheaper, but so cheap as to make the change from one to the other attractive.

69. Pierce, J. L., Kostova, T., & Dirks, K. T., *The State of Psychological Ownership: Integrating and Extending a Century of Research*, Review of General Psychology, 7(1), 84–107, 2003. IPCC, *Climate Change 2022: Mitigation of Climate Change, Chapter 10: Transport*, 2022.

6 Conclusions: Finding the Right Mobility Mix

The mobility of the future will not just be depending on electrifying cars but would emerge from integrating the innovations discussed in this paper with those still to come. Today's model leaves a car parked for 95% of its time, travelling at roughly a quarter of its designed speed with only a third of its seats occupied, while consuming space, emitting CO_2 and demanding considerable time and effort from its users.[70]

Some of what follows is visionary: aircraft above cities, vehicles that drive themselves. Some of it is almost old-fashioned, yet no less transformative: the train reinvented, and roads intelligent enough to guide the cars on them. What unites them is not the technology, but what the technology does to the cost of a kilometre travelled - in time, in money, in health, and in space. How much we value these, depends on where a country starts. A rich, sparse country and a dense, developing one will not and should not, converge on the same mobility mix; the right answer for each depends on income, density, and how deliberately the two are matched, not on a single global target for kilometres travelled. how well they connect, with each mode serving the journeys for which it is best suited. Progress should therefore be measured through accessibility, emissions, space, time and affordability, alongside safety and useful service.

This future requires deliberate choices about investment, regulation, ownership and everyday behaviour. The technologies create possibilities; turning them into a coherent, inclusive and sustainable mobility system, one genuinely matched to where each country starts, is a responsibility we share and build that future.

70. McKinsey & Company, *Shared mobility: Sustainable cities, shared destinies*, 2023.

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