Unlocking a 21st Century Mobility System

- How to Rethink the Future of Mobility and Restore Leadership in Transportation Innovation

COALITION FOR
Reimagined Mobility
Transportation Policy that Puts People First

SAFE

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To the Reader

Since the turn of the century, the transportation policy world has posited that advancements in technology and innovative public policy would deliver transformative changes allowing us to effectively address major challenges linked to how people and goods move around the world: emissions and air quality, equity, access, efficiency, and safety. The aspirational product of this inflection point was dubbed a 21st century transportation system.

The thesis went that the intersection and acceleration of trends in vehicle automation, connectivity, electrification, new models of access, and applications of big data and analytics would unlock new safer, cheaper, cleaner, more equitable, and more efficient mobility options for all. Unfortunately, more than two decades into the century and we're still talking about the aspiration of a 21st century system instead of benefiting from its impact.

SAFE founded the Coalition for Reimagined Mobility (ReMo) on the premise that bold action and commitment are necessary to unlock the potential of transportation innovation that truly benefits society at large by addressing our major challenges and improving people's daily lives. At ReMo we believe that this action starts with convening a diverse set of stakeholders to understand and identify what has prevented progress toward addressing the challenges of our time – from consumer demand and acceptance, to market realities and policies that enhance national security and leverage competitive strength – and ends with effective coordination across the public and private sectors. We believe ReMo is the right organization at the right time to lead this bold action.

In this report we document the opportunities and plan a course to deliver on this potential. We are eager to roll up our sleeves and get to work on the hard task of turning words into action to reimagine a global mobility system that is better for both people and the planet.

Avery Ash
Executive Director
Coalition for Reimagined Mobility (ReMo)

Preface

Successful efforts to address global transportation challenges require local context and consideration.

It is worth a particular note that while the themes of this report have global application, they primarily (but not exclusively) leverage examples and data that relate to non-rural areas and populations in the United States. As the first of the "hard truths" that will be outlined, it is important to keep in mind that there are no silver bullets. While the broad environmental, societal, and security challenges tied to transportation and energy may be global in their application, they are local in their nature and solutions.

Similarly, ReMo believes that, while the defining technologies of a 21st century mobility system are likely to share many common characteristics and trends across the globe, to what extent they are adopted and in what combination will look very different across regions, populations, cultures, and environments driven by the policies adopted in each locale. The evidence of these differences and disparities is well documented in the 20th century transportation system. For example, in some locales and populations, taxi and now ridehailing services have been widely adopted, in others – whether because of a lack of consumer acceptance, the action of policymakers, or market economics – these services have not. The same holds true for other innovations that were the hallmark of 20th century mobility from personal automobiles to high-speed rail to public transit to electric bicycles.

While policy analysis and specific recommendations for action require local context to be accurate and effective, ReMo is a global initiative. As such ReMo plans to build on this report with follow-on research, analysis, insights, and recommended actions that are specific to understanding and delivering reimagined mobility in a variety of global regions, populations, and markets. For example, what are the recommendations for successfully unblocking the deployment and scale of innovative new technology in American vs. European cities? What policy changes would be impactful in more effectively meeting the mobility needs of seniors in wealthy rural vs. lower income suburban areas? How can nega-mile offerings increase the quality of services available to families in warm versus cold climates? Which mobility trends and innovations can be most effectively replicated and scaled on both sides of the Atlantic to enhance people's freedom to move and stay connected? Answering these questions requires thoughtful research and insights from a broad set of stakeholders to ensure that the technologies that meet the needs of users are successful in their testing, deployment, and scaling.

ReMo is the right forum at the right time to conduct this research, convene to drive this feedback, and explore how we can more effectively deliver on the potential of a 21st century mobility system.

Executive Summary

This report sets out to reset the narrative around transportation technology and rethink the way the world moves.

Reimagined mobility is a forward-looking, fit-for-purpose, and people-centric approach to transportation systems and services that harnesses technology, accounts for changing societal needs, and centers around the importance of energy security and environmental sustainability. It includes individualized solutions and a multimodal approach to addressing different mobility needs based on location, circumstances, and personal preferences.

A successful reimagining of mobility needs to be equal parts aspiration and reality check. Imagine how a commute in an electric vehicle, or a shared autonomous shuttle, or a purpose-built autonomous pod might make your time more productive and enjoyable. Or how a sustainable micromobility option, such as a bicycle or e-scooter, could move you through a dense urban center faster and more efficiently. What if you didn't have to take the trip at all? It is, however, essential that this reimagining remains human-centered and grounded in the realities and dynamics that will dictate success and matches innovations with people's everyday needs and recognizes levels of acceptance.

A 21st-century mobility system is defined by new technologies and services that have the potential to address environmental responsibility and energy security challenges by accelerating decarbonization and drastically reducing the global transportation sector's dependence on oil. This is a system where affordable and accessible multimodal mobility options can ensure that everybody, regardless of their circumstances, has reliable and convenient access to clean and safe transportation, whenever they need it.

This vision for a mobility future prioritizes roadway safety and the meaningful integration of emerging technologies such as artificial intelligence (AI), machine learning, and the Internet of Things (IoT). It harnesses the combined power of ubiquitous connectivity, automation, electrification, and advanced data analytics to create more integrated and intelligent transportation systems. Additionally, this new mobility future leverages the respective strengths of the private and public sectors to deliver compelling mobility choices and efficient, financially sustainable, and resilient transportation systems.

In this new mobility future, the Coalition for Reimagined Mobility (ReMo) envisions dynamic companies based in the United States and allied countries setting the global pace in transportation technology innovation, deploying digitally secure products and services built with resilient supply chains, which bolsters the economic and national security of like-minded democratic nations. Ultimately, a reimagined mobility future contributes to improving people's everyday lives, a strong and productive economy, and healthy and vibrant communities.

This report addresses head on why, more than two decades into the 21st century, we are still waiting for, and in some cases have fallen behind in achieving, reimagined mobility. It asserts the reality that there are no silver bullet solutions, and cookie cutter approaches to changing the transportation system – for example focusing only on vehicle electrification or shared use vehicles – are doomed to fall far short of their potential.

Recognizing these realities, this report focuses specifically on the challenges and opportunities faced by the United States in delivering reimagined mobility. The themes and ideas are, however, relevant to all like-minded democratic nations treading their own path to reimagining mobility.

New mobility technologies and services have the potential to act as force multipliers, ***but that will not happen overnight.***

ReMo's research and stakeholder engagement has informed this seminal report, which aims to reset the mobility conversation in the United States in particular. The report sets out a thematic roadmap for future ReMo work and initiatives that will challenge the status quo of transportation thinking, both in the United States and globally.

New mobility technologies and services have the potential to act as force multipliers, but that will not happen overnight. Furthermore, policy changes alone will not deliver reimagined mobility. Putting the market incentives, policy, regulations, and institutions in place to encourage and foster these shifts is a collective task. This report addresses the hard truth that change will only happen when the private and public sector work together effectively to transform the transportation system, which means that we must be able to both chart a long-term vision while also executing short-term plans to get us there.

This report also articulates why it is essential for the United States and its allies to take swift action to address a dangerous complacency towards technology's substantial impact on transportation systems and infrastructure. Whether it is electric, connected, or autonomous vehicles, or the underlying infrastructure and telecommunications technologies that support them – global peers and particularly China have captured the lead.

Given the importance of the automotive and technology sectors to the United States' and other nations' economies and industrial bases, falling behind China has serious implications for economic competitiveness, national security, and achieving a more equitable society. There is a deep connection in these countries between economic security and national security because economic prosperity is the engine that drives industrial prowess, resilient infrastructure, as well as ensuring a stable and well-functioning democratic society.

Yet today's siloed, fruitless debates about the future of transportation are typically focused on one of two fallacies: that advanced mobility technologies have been an overhyped failure; or that the United States still leads the world in transportation innovation. Both arguments are false, and both hold back the ability to effectively compete with an increasingly powerful China and deliver a mobility future that benefits both people and the planet.

Finally, this report conveys the policy, consumer, and business challenges to realizing a mobility future that will revolutionize the movement of people and goods, and identifies areas where new policy solutions and thoughtful, collaborative action from multiple stakeholders are needed. This report's purpose is ultimately a call to action for all those who care about shaping more connected, secure, and sustainable mobility outcomes and options; the prosperity of the United States and allied nations; and addressing the implications of failing to seize the opportunities available. The focus within this report is the challenge to reimagined mobility within the United States, but the call to action is relevant on a global scale.

KEY FINDINGS

To step thoughtfully into the topic of reimagining the mobility landscape from what it is today, this report begins by providing a historical overview of how the current transportation system in the United States came to exist, from the dawn of the automotive age through to today's burgeoning electrified and highly connected mobility industries, services, and systems. While much of the focus and analysis of this paper is on the United States, the themes and lessons can be applied more broadly. Subsequent ReMo reports and recommendations will also focus on what is needed to reimagine mobility in a harmonized and mutually beneficial way in other countries.

Navigating the convergence of transportation, technology, and connectivity represents a profound shift in the way society operates, and it is this very transformation that highlights the critical opportunity for stakeholders to work together to shape the future of mobility. The United States and its allies are now at an inflection point where they must choose to fully accelerate toward a new mobility paradigm.

Today's New Mobility Landscape

The transportation sector is undergoing a once-in-a-century transformation, prompted by advancements in connectivity, automation, electrification, and emerging and enabling technologies around artificial intelligence, robotics, advanced data analytics, and more. Yet for all this technological progress, there has been limited scaling of these technologies and in some cases, progress has stalled. An honest evaluation of the current mobility landscape for each trend, covered later in this paper and summarized here, is long overdue. It is also essential to chart a successful path forward to unblocking the barriers to scale and addressing consumer acceptance and market realities to achieve exponential gains related to safety, security, accessibility, and sustainability. In other parts of the world, these technologies and trends are more advanced in their deployment and public acceptance, but this report focuses specifically on the experience in the United States.

Autonomous Vehicles

AVs have promised to fundamentally change the way people and goods move and their value-add to society, as part of a safer, more efficient, and accessible transportation system, has been the underlying premise for investment, development, and testing to date. Since 2020, operational AV testing has been underway in limited commercial markets for public use, and data indicates there's been a steady progression of bringing AV technology to market. But despite this documented progress, real barriers must still be addressed to scale AVs and fulfill their promise. Policy is one barrier, where specifically the lack of U.S. federal leadership to ensure AV testing and deployment is distributed across markets has resulted in limited impact to the broader mobility system, as are challenges with consumer acceptance and market dynamics. An equal and additional barrier is the insufficient parallel investments needed for enabling technologies that are fundamental to the feasibility and successful deployment of AVs at scale.

Vehicle Connectivity

Software-defined vehicles are coming to scale today alongside a robust communications infrastructure network that brings connectivity to the vehicle. From telematics platforms that connect the vehicle to the outside world, to cellular vehicle-to-everything (C-V2X) communications for safety, the technical capabilities of the connected car are rapidly evolving. Though, while vehicle connectivity has provided new consumer experiences, advancements in roadway safety, and revenue benefits to OEMs, suppliers, and other stakeholders, there have been barriers to progressing beyond this point. The biggest barrier is centered on data application and monetization, and that blocker will persist without meaningful partnerships and a combination of policy and market forces to drive collaboration across the variety of public and private stakeholders that are involved.

Vehicle Electrification

Electric vehicles (EVs) currently account for 8.6 percent of new vehicle sales in the United States, and 14 percent of new vehicle sales globally.[1] While a growing number of countries, including the United States, have set ambitious targets for

[1] "Global Electric Car Stock, 2010-2022 – Charts – Data & Statistics." n.d. IEA.

EV adoption, there is concern that steps are needed to ensure prices fall and adoption rises in order to meet these goals. Transportation is, in general, becoming increasingly unaffordable – in 2022 U.S. households spent an average of $12,295 or 16.9 percent of their after-tax income on owning and maintaining an automobile.[2] It is the second largest expenditure after housing and continues to increase, acutely impacting low-income households where transportation costs require 30 percent of after-tax income. In this context, the higher up-front sticker price of EVs makes a big difference in people's purchase decisions – the average price of a new EV is roughly $64,000.[3] Additionally, policymaker and industry efforts to scale up EV adoption are contending with the increasing potential of new strategic resource crises. Large quantities of minerals such as copper, cobalt, nickel, lithium, aluminum, and other rare earth elements are required for EVs and their batteries.[4] China currently dominates nearly all aspects of the critical mineral supply chain – from mining and mineral processing to advanced component production, manufacturing, and recycling.[5] This makes a single country a potential chokepoint for the raw materials and necessary components required to produce new technologies, which requires action and investment to ensure that the market and producers become sufficiently diverse.

Mobility-as-a-Service (MaaS)

MaaS is an evolving concept that integrates various modes of transportation – such as public transit, rideshare, bike-share, micromobility, and more – into one integrated and seamless service offering.[6] In much of the world, MaaS platforms are driven by the public sector and integrated at their core with fixed-route transit services. In the United States, it has been Transportation Network Companies (TNCs) such as Uber and Lyft that have driven the experience of on-demand mobility. Today, 26 percent of Americans use these services monthly, which shows that people value the utility of convenient on-demand mobility that is accessible via an app.[7] While each of the components of MaaS have their own challenges to scaling and integration across markets, the crosscutting challenge is how to realize the benefit of this user-centered approach while addressing the entrenched challenges to its success.

Vehicle Design

The potential transformation offered by new mobility technologies does not just relate to their propulsion, connectivity, or software, but also their spatial form factor. Novel vehicles that are more efficiently designed and right-sized for specific use cases – such as shared robotaxi vehicles that are more easily accessible to people with physical disabilities – offer the potential to deliver major efficiencies in the way vehicles are manufactured and deployed. This includes the consideration that reductions in the size of EV batteries alone could

[2]Transportation Economic Trends: Transportation Spending - Average Household. (n.d.). Bureau of Transportation Statistics. data.bts.gov/stories/s/Transportation-Economic-Trends-Transportation-Spen/ida7-k95k/

[3]Electric Car Prices: The Average Electric Car Cost in 2023. (n.d.). Find My Electric. www.findmyelectric.com/blog/electric-car-prices/

[4]Mineral requirements for clean energy transitions – The Role of Critical Minerals in Clean Energy Transitions – Analysis—IEA. (n.d.).

[5]Clean energy supply chains vulnerabilities – Energy Technology Perspectives 2023 – Analysis. (n.d.). IEA.

[6]Hensher, D. A., Mulley, C., Ho, C., Wong, Y., Smith, G., & Nelson, J. D. (2020). Understanding Mobility as a Service (MaaS): Past, present and future. Elsevier.

[7]Flynn, J. (2023, June). 20+ Riveting Ridesharing Industry Statistics [2023]: Average Ridesharing Revenue, Market Share And More—Zippia. Zippia.

cut lithium demand by as much as 42 percent by 2050.[8] However, outdated vehicle design regulations and the realities of consumer demand in the United States have limited progress. This has also meant conceding the smaller, more affordable segment of the global market to manufacturers, particularly Chinese manufacturers, who are aggressively targeting this sector.

Transportation Data and Analytics

While much of the focus on reimagining mobility centers on the vehicles and technologies that will transform the transportation sector, there is substantial opportunity for data and analytics to serve as a force multiplier for these changes. Leveraging the explosion of new data and insights available from increasingly connected vehicles and infrastructure has the potential to provide real-time and historical information that will allow more effective planning, more efficient operation, and more transparent performance to users, businesses, policymakers, and public authorities. While there is a tremendous amount of data being generated by and about the transportation mobility sector, there have been limiting factors to seeing the impact of this trend on a system-wide level. This includes the lack of a coordinated approach, such as standardization, to how to use and structure data; inadequate public funding to source and use available data; challenges of how to monetize vehicle data and analytics; and an uncertain and shifting landscape around how to consider privacy and security of data that can be used to make better decisions. Addressing these challenges requires coordination and communication between the public and private sectors to agree on the impact desired and then identify the data and analytics required to drive this outcome.

Nega-miles

The mile not traveled in a personal motor vehicle including trip reduction or trip optimization from the convergence of technologies, is a concept this report refers to as the nega-mile.[9] Leveraging the opportunities for major rethinking of policies, programs, and investments to harness nega-mile concepts can also reduce the current demand on critical minerals and industrial materials used to reduce the sector's dependence on oil. A strategic systems approach to how best to use technology to achieve less miles traveled can yield substantial environmental benefits and a greater quality of life for those who gain time back from a trip not taken.

Across each of these technological trends the new mobility landscape is at a crossroads, with significant advancements achieved but also continued challenges that prevent scaling and integration. For the United States to reassert its leadership in this dynamic and evolving sector, there is an urgent need for strategic investments, public policy and guidance, and a cohesive approach that brings together industry and government stakeholders; prioritizes innovation; and addresses economic, environmental, and security concerns.

An Evolving Global Playing Field

China as the new transportation technology superpower

While these new mobility technologies are experiencing an uneven path to mainstream deployment and acceptance in the United States and many other allied countries, the progress in the People's Republic of China is much more advanced. Through the implementation of ambitious, state-led industrial

[8]Riofrancos, T., Kendall, A., Dayemo, K., Haugen, M., McDonald, K., Hassan, B., Slattery, M., & Xan, L. (2023). Achieving Zero Emissions with More Mobility and Less Mining. Climate and Community Project (CCP). p 7

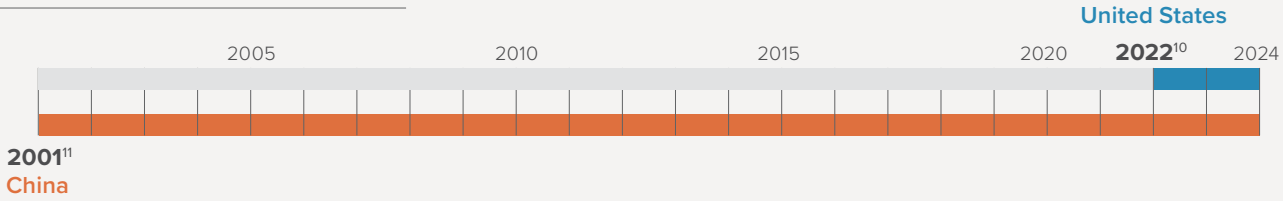
[9]Watts, R. (2017, October 26). The Mile Not Traveled. Vermont Public.

Figure 1. The Mobility Leaderboard.

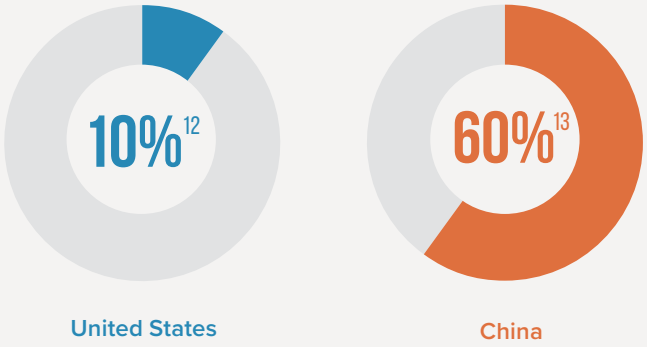
China is far ahead of the United States
when it comes to new mobility technologies.

Electric Vehicle Adoption

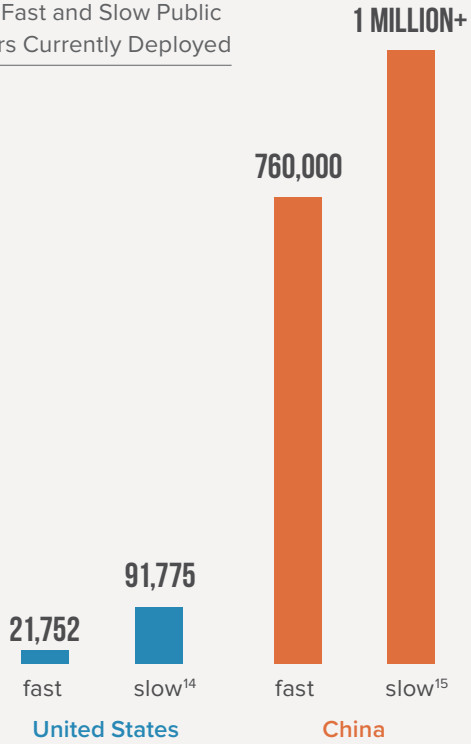
Date of First Major National Policy on EVs



Global EV Sales Market Share

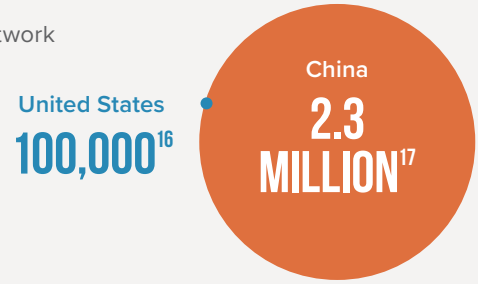


Number of Fast and Slow Public EV Chargers Currently Deployed

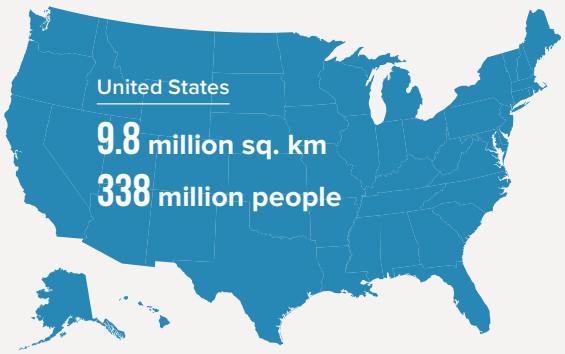


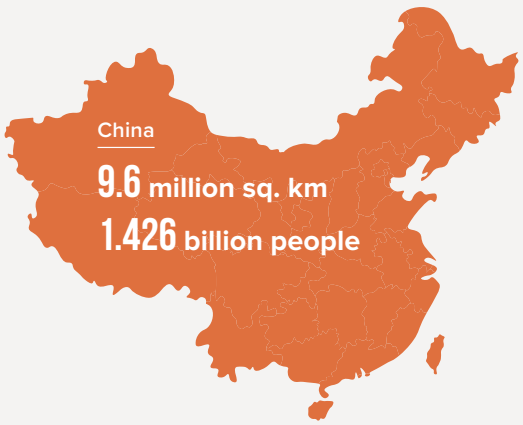
5G Adoption

Number of 5G Network Base Stations



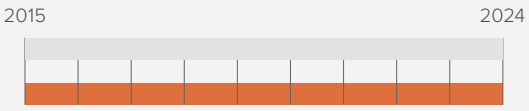
Country Sizes





Autonomous Vehicle Adoption

Date of First National Policy on AVs



China **2015**[18]

United States **Still no national policy on AVs**

Commercial Freight AV Deployments

United States and **China**

Growing ad hoc deployments in off-road environments[22]:

China

Major public-private consortium plans to deploy along three major Eastern inter-city corridors.[23]

Commercial Passenger AV Deployments

United States

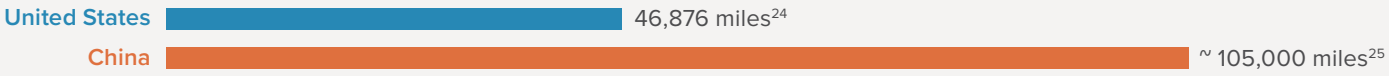
Austin, Phoenix, San Francisco[19]

China

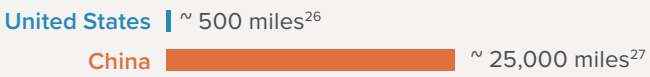
Beijing, Chongquing, Guangzhou, Shanghai, Shenzen, Wuhan[20]

Infrastructure Development

Size of Interstate/Expressway Network



Size of High-Speed Rail Network



[10]Inflation Reduction Act, passed August 2022

[11]Year that EVs designated as a priority science project in China's 10th Five-Year-Plan. See Yang, Z. (2023, February 21). How did China come to dominate the world of electric cars? MIT Technology Review. and China National People's Congress. (2001). Report on the Outline of the Tenth Five-Year Plan for National Economic and Social Development.

[12]International Energy Agency. (2023). Global EV Outlook 2023: Catching up with Climate Ambitions. OECD. p 20

[13]Ibid p 16

[14]Sickels, D. (2022, August 17). China has 65% of public EV charging stations worldwide. The Buzz - Electric Vehicle News.

[15]Trends in charging infrastructure – Global EV Outlook 2023 – Analysis. (n.d.). IEA.

[16]Mannion, T. (2022, October 25). What is the impact of the U.S. lagging on 5G? BDO Global.

[17]GSM Association. (2023, March 26). GSMA Mobile Economy China Report Forecasts China will be first market in the world to reach 1BN 5G Connections by 2025.

[18]The year that vehicle automation, the "Internet of Vehicles and the Internet of Vessels" and the "internet-based operation of transport infrastructure and means of transportation and the digitalization of operation information" were designated as priority areas in China's 13th Five-Year-Plan. See The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020). (2015). p 83

[19]Muller, J. (2023, August 29). Robotaxis hit the accelerator in growing list of cities nationwide. Axios.

[20]Doll, S. (2023, March 17). Baidu (BIDU) robotaxis offering fully-driverless rides continue to take over China. Electrek. and Roberts, G. (2023, July 11). China allows unmanned robotaxis to operate in key cities. Just Auto.

[21]Taube, D. How partnerships tie into Gatik's view on middle-mile autonomy. (2023, July 11). Trucking Dive.

[22]Feifei, F. (2023, June 30). China presses the accelerator on driverless vehicles. Asia News Network.

[23]China Highway & Transportation Society. (2023, August 1). The Vehicle-Road Collaborative Innovation Consortium established three national societies to jointly promote the integrated development of vehicle, road and cloud. www.chts.cn/xw/XHDT/art/2023/art_27fb7fca-14e444a7a2b3765a69c15507.html

[24]Federal Highway Administration. (n.d.). Interstate Frequently Asked Questions. highways.dot.gov/highway-history/interstate-system/50th-anniversary/interstate-frequently-asked-questions#question4

[25]Rodrigue, J.P. (2020). Length of the Interstate Highway System and of the Chinese Expressway System, 1959-2021. In The Geography of Transport Systems (5th ed.). Routledge.

[26]U.S.: Highspeed track length 2021, by section. (n.d.). Statista.

[27]China: Length of highspeed rail operation network 2021. (n.d.). Statista.

policies and aggressive investment across the sector, including EVs, AVs, 5G wireless installations, high-speed rail, and freeways, China has signaled that it intends to be a global leader in many advanced transportation technologies.

Beijing's policies and their relative effectiveness, as seen Figure 1, can be measured through metrics such as volumes of EV sales and exports, charging infrastructure deployment, the scale of wireless telecommunications installations, scalable pilot programs for AVs in major cities, and the modernization of road and rail infrastructure.

Understanding the scale of China's transportation technology progress is important because mobility-related industries are crucial to the industrial base of nearly every advanced economy. The U.S. automotive industry, for example, contributes up to five percent to the nation's GDP, infusing $1 trillion annually into the economy.[28] Europe's automotive sector yields an annual trade surplus of $85 billion,[29] while Japan's auto sector accounts for nearly 18 percent of all Japanese exports.[30] As the global shift towards electric and autonomous vehicles accelerates, it will certainly impact the industrial bases of U.S. and allied economies, which have proven to be crucial in recent years in emergencies – from ventilator manufacturing during the pandemic[31] to defense needs during the Ukraine-Russia war.[32]

This report starts to identify some of the risks of China's dominance of advanced transportation technologies. While not always the primary innovators, China's growing focus in the intellectual property and expertise associated with connected and autonomous vehicles (CAVs) raises significant national security concerns for the United States and other nations. This is especially worrisome due to potential cybersecurity vulnerabilities linked to China's influence in autonomous transportation. There are also very real exploitation and cybersecurity risks associated with a hostile foreign actor controlling or influencing connected and autonomous transportation systems and hardware that may be deployed within the United States.

Furthermore, China's growing influence in CAV technologies is also guiding the direction of global standards in the transportation sector, potentially positioning them as a dominant force in shaping the future of transportation. Additionally, the vast amount of data generated by CAVs has the potential to offer Chinese entities, as dominant players in the market and patent holders, extensive access to valuable and sensitive information, with implications for both personal privacy and technological advancement.

Lastly, technologies conceived for civilian use, for example LiDAR, also have military applications,[33] presenting added layers of concern. Both U.S. and Chinese militaries utilize LiDAR for autonomous navigation in unmanned vehicles. The Chinese Communist Party's (CCP) possible imposition of an export ban on LiDAR technologies, coupled with their strategy of merging military and civilian tech advancements, underscores the urgency for the United States and its allies to respond proactively.[34] Inaction risks yielding significant ground to an ambitious Beijing across the spheres of technology, economy, and defense.

The policy, consumer, and industrial barriers to a reimagined mobility future

For the United States and allies to make progress on advanced mobility technologies, industry, policymakers, and other key stakeholders must effectively address blockers and take proactive, coordinated steps to address them.

Public policy is often pointed to as the singular blocker to the testing, deployment, and scale of new transportation technologies, but the failure to account for other key barriers will ultimately mean that efforts to facilitate these advancements and capitalize on their potential for impact will fall short. While the barriers that need to be addressed are many, they can be considered in three distinct categories. These policy blockers are common to the United States, its allies, and partners, but

[28]Alliance for Automotive Innovation. (2022). The Driving Force.

[29]The state of the EU auto industry. (2022, September 30). ACEA - European Automobile Manufacturers' Association.

[30]Japan Automobile Manufacturers Association, Inc. (2022). The Motor Industry of Japan.

[31]How a manufacturing moonshot was made. (2022). McKinsey & Company.

[32]U.S. Military Support for Ukraine is Helping Put American Industry Back on Track. (2023, September 23). German Marshall Fund of the United States.

[33]Sutter, K. M., & Sayler, K. M. (2023). U.S.-China Competition in Emerging Technologies: LiDAR. U.S. Congressional Research Service.

[34]Zhang, S. D., Yuan Yao, Jack. (2023, April 5). China's Proposed Export Ban on LiDAR Technology: What Impact Will It Have on the Automotive Industry? AlixPartners.

in this report ReMo analyzes the impact of these blockers in a U.S. context. Future work will analyze how to tackle these challenges in other markets.

Policy

Policy blockers are present at the federal, state, local, and international levels. These include restrictive and outdated rules around vehicle design, limitations on where and how new technologies can be tested, insufficient public investments to support new technologies, and even the failure to coordinate and communicate between agencies at various levels to provide regulatory certainty needed to drive private investment. While targeted policy changes to overcome existing inertia are key to delivering on the promise of a 21st century mobility system, it is important to recognize that policy changes alone will not guarantee the success and impact of new technologies.

Consumer acceptance and demand

The success of new modes, designs and approaches to mobility are contingent on consumers accepting these new offerings and opting to utilize them to meet their transportation needs. While there often is initial enthusiasm for new technologies, we have seen repeated examples where this excitement wanes and consumer enthusiasm turns to skepticism or even backlash. High-profile crashes and media coverage emphasizing technology's limitations have exacerbated these concerns. The public's limited exposure to AVs has most recently contributed to this skepticism, even while robotaxi services expand in cities like San Francisco, Austin, and Phoenix. A recent J.D. Power survey found that positive first-hand experiences tend to build consumer trust and overcome the fragility of consumer acceptance, with 47 percent of robotaxi riders gaining trust during a ride, and only 2 percent of riders losing trust in robotaxi capabilities during a ride experience.[35] Similar skepticism exists with connected vehicles, where 63 percent of U.S. consumers now worry about data privacy and 54 percent fear cyberattacks.[36] When ridesharing services first entered the market they enjoyed rapid adoption and support, before consumer and policymaker support eroded in many markets. This same challenge

High cost was the top ranked reason for not purchasing an electric vehicle.

60%

of survey respondents listed cost as a major reason keeping them from purchasing an EV.

Source: Energy Policy Institute at the University of Chicago Survey, 2023

of consumer preferences is front-and-center with vehicle design considerations where aspirations for right-sized or shared-use vehicles run headlong into increasing consumer demand for large, individually owned cars and trucks. Further, the high cost of EVs remains a deterrent which impacts

[35]2023 U.S. Robotaxi Experience Study. (2023, October 19). J.D. Power.

[36]Consumer interest in 'Connected Cars' is rising slowly but ongoing concern over privacy and the threat of cyber-attacks hamper greater demand. (2021, September 1). Harris Poll. theharrispoll.com/briefs/connected-cars/

consumer demand. In a 2023 poll, high cost was the top ranked reason for not purchasing an electric vehicle, with 60 percent of survey respondents listing cost as a major reason keeping them from purchasing an EV.[37] Consumers are also slow to adopt due to concerns about charging infrastructure and charging availability despite the improvements in battery range. A failure to account for the transportation wants and needs of the public, and even how this will vary by market, means that potentially impactful innovations may ultimately fail to gain traction and deliver results.

Industrial barriers and macro considerations

This final category of blocker includes the host of "realities" that prevent otherwise impactful transportation technologies from testing, deploying, and scaling. This would include challenges like funding and investment challenges with the need to deliver near-term investor return in sectors where it may take years to monetize; insufficient or degraded public infrastructure; liability and insurance structures that are incompatible with a reimagined mobility future; workforce development challenges; political polarization and varying technologies being framed ideologically, and concerns from labor on the impact of changes. This paper identifies and unpacks the most impactful and timely barriers in this category.

Overcoming these barriers in a democratic values framework

A famous Chinese proverb states "if you want to become wealthy, build a road first." There are lessons to be learned by the United States and its allies about how our global peers, in particular China, have addressed these same categories of complex blockers in their own countries. The most important of these lessons is that disruptive and wide-scale innovation and deployment of the technologies that enable reimagined mobility will not occur organically and will require a roadmap of bold and supportive collaboration between the public and private sectors.

China's success in prioritizing autonomous, connected and electric mobility and its convergence with digital communications technology does not mean the United States should replicate Chinese policies wholesale. China has an authoritarian one-party state, with a socialist market economy, under the purview of the CCP. For all of China's impressive successes in transforming itself in a few short decades from an impoverished nation to the world's second largest economy,[38] it remains an authoritarian state with a very different world view to that of democratic capitalist nations. As such, the levers that China has available to address blockers to new transportation technologies are very different from those in in a democratic, free-market environment like the United States. In China's socialist market economy, successful businesses are required to conform to the aims of the CCP, surveillance is ubiquitous, and individuals' privacy is not protected.[39]

The United States and its allies can and must create their own roadmap to accelerate a transportation technology revolution, leveraging the same factors that enabled the automobile transportation system's ability to massively expand people's freedom and economic opportunity through mobility, and built the strength of the U.S. technology sector. Market capitalism is core to U.S. economic strength – 9 out of 10 of the world's largest public companies are U.S. corporations.[40] Market capitalism, where the private sector owns and controls the means of production, was central to the birth and growth of both the U.S. automotive and technology industries and the employment opportunities and prosperity enabled by them. The role of strategic policies and effective policy tools to leverage the strength of the private sector will be central to any successful attempt to recapture the lead from China.

The successes and positive feedback loops generated by recent ambitious industrial policy packages in the United States underscore this point. The Inflation Reduction Act has created supportive feedback loops in energy policy, particularly transportation, that will create an estimated $2.9 trillion of cumulative investment opportunity by 2032.[41] Building on and replicating the impact of this program will be essential for democratic nations to implement bold policy actions that leverage the strength of the market to invest in reimagined mobility.

[37]Many Americans aren't yet sold on going electric for their next car, poll shows. (2023, April 11). PBS NewsHour.

[38]According to 2022 World Bank data, the United States is the world's largest economy with gross domestic product (GDP) of $25,462 billion. The People's Republic of China is the world's second largest economy with GDP of $17,963 billion.

[39]Wakabayashi, D., Chang, C., & Fu, C. (2022, October 17). In Xi's China, the Business of Business Is State-Controlled. The New York Times.

[40]Neufeld, D. (2022, December 26). Ranked: The 100 Biggest Public Companies in the World. Visual Capitalist.

[41]The U.S. is Poised for an Energy Revolution. (2023, September 14). Goldman Sachs.

RECOMMENDED STRATEGIES

With global peers already pulling ahead with advanced transportation and communication technologies, a failure to act now risks conceding the leadership mantle in these transformative sectors. The United States therefore needs to implement a coordinated strategy on new mobility technologies, which will require industry and policymaker collaboration and prioritization on the blockers and barriers identified above. Suggestions for immediate action that should be undertaken include:

- Designate, communicate, and support **new mobility technologies and services** as a national and economic security priority.
- Past and recent history shows that the forces of market capitalism can be directly and positively impacted through supportive system dynamics and feedback loops stimulated by ambitious federal policies. Therefore, it is worth noting the need for an **all-of-government digital industrial strategy** that accounts for new mobility technologies that are now converging with expanded digitalization and connectivity. Such a strategy would serve as a foundation to enable enhanced national security, greater economic productivity, greater personal choice, and ultimately human flourishing.
- Reform outdated policy and introduce **new policy frameworks** that will facilitate a reimagined mobility future while supporting U.S. and allied innovators to develop and scale new transportation and logistics solutions for moving people and goods.

First, there is a need to address the regulatory barriers and gaps that inhibit the transformation of the U.S. vehicle fleet, from both a form factor and efficiency perspective. The U.S. vehicle regulatory system is outdated and presents barriers to a sustainable transportation transition that suits people's different mobility needs. Regulations like the Federal Vehicle Motor Safety Standards (FMVSS) are an example of an outdated policy framework that only accounts for vehicles designed to be human driven and of a certain vehicle weight. The lack of diverse vehicle designs threatens both the U.S. competitive edge and broader global sustainability goals and limits the variety of mobility options available to people.

Moreover, while there have been advances in emissions reductions and fuel economy, the prevailing trend towards larger, less efficient vehicles counteracts these benefits. A revamped regulatory approach, responsive to the evolving mobility landscape while accounting for consumer demand, is crucial to ensuring U.S. global leadership in the sector.

Second, America's transportation funding and planning mechanisms need a significant overhaul. The funding and design of the U.S. transportation system, largely constructed for the 20th century, has not evolved in tandem with the convergence of the transportation, energy, and technology sectors.

Despite significant federal investments in roads, 43 percent of America's infrastructure remains in suboptimal condition.[42] The Highway Trust Fund, primarily funded by gas taxes that haven't changed since 1993, is unable to cope with the demands of modern infrastructure, especially when considering the aspirational rise of vehicles that contribute less gas tax revenue per mile traveled. Additionally, despite the evident need for Intelligent Transportation System (ITS) solutions and products and wireless communications for emerging mobility solutions, current federal policies are not adequately promoting long-term, foundational investments.

While there have been advances in emissions reductions and fuel economy, ***the prevailing trend towards larger, less efficient vehicles counteracts these benefits.***

These antiquated approaches to funding and planning transportation mean that many Americans do not get to enjoy a modern, well-functioning mobility system with high quality infrastructure. To facilitate modern mobility and infrastructure needs, the United States must rethink federal policies, prioritize diverse transportation modes, and incentivize innovative infrastructure investments.

Third, existing liability frameworks, designed mainly for human-driven systems, now face challenges with the fusion of human and AI-driven mobility. For AVs and vehicles with advanced driver assistance technologies, adopting a safety-focused liability approach could foster innovation.

[42] 2021 Report Card for America's Infrastructure: Roads. (n.d.). American Society of Civil Engineers. infrastructurereportcard.org/cat-item/roads-infrastructure/

For example, no-fault systems, which prioritize safety without laying blame, have seen successful use globally and are currently adopted in 12 U.S. states. The potential of AVs to significantly reduce vehicle crashes suggests a pressing opportunity to reimagine and improve such no-fault frameworks, benefiting both the economy and society at large.

Other potential policy options include strict liability (liability which does not depend on actual negligence or intent to harm), safe harbor provisions, or even a National Connected and Autonomous Vehicle Injury Compensation Program. Any potential policy reform should be evaluated based on how it affects key societal and risk management policy concerns, such as public safety, the deployment of AV technology, crash prevention and rehabilitation, the cost of insurance to consumers and businesses, access to justice, and reducing social inequity associated with transportation.

Finally, the United States should consider a new focus on the reuse and efficient utilization of resources – commonly called the circular economy. Rather than simply disposing of items, a circular economy presents meaningful benefits, such as helping the environment and enhancing national security.

The minerals and materials in vehicles are infinitely reusable and recyclable. Once those materials are in the United States or in allied countries, they are essentially an above ground mine, which alleviates the need and dependence on new minerals from other countries. The United States currently lacks a federal end-of-life vehicle (ELV) recycling policy like other global automotive hubs such as the EU, Japan, Korea, and China, all of which have implemented advanced frameworks.

Though the United States has had success in other instances relying on a market-driven approach, this policy gap affects the strategic reliability of materials crucial for vehicle manufacturing and clean energy technology. Implementing policies that support technologically advanced vehicle recycling can enhance supply chain resilience, reduce environmental impact, and complement investments in the transportation sector and critical mineral supply chains to enhance national security. The benefits of a circular economy in mobility for people include increased product longevity and repairability, more affordable mobility through new models of services and vehicle access, and reduced pollution and negative environmental impacts in communities. In particular, the United States needs to consider a policy for black mass – the material from ground up used batteries – so that it is not reprocessed in countries on which the United States and its allies cannot depend. It is imperative that this issue is framed as one of national security and not just an environmental issue to ensure it gains bipartisan support.

*The United States should consider a new focus on the reuse and efficient utilization of resources – commonly called the **circular economy.***

The Future of Mobility

Much has been written about the promise of a 21st century transportation system. This promise has centered on the convergence of innovations across systems, technology, and communications to transform and improve the way people and goods move, to deliver solutions that address the world's aging 20th century infrastructure, and that solve our most systemic problems: congestion, safety, reliability, oil dependence, climate change, air quality, resiliency, cost, and disparities in access and quality of services, among others.

Historically, when these problems are identified, the focus is on treating the symptoms and not addressing the root causes. Herein is a level set that frames the changing mobility ecosystem and illustrates a vision for what a new mobility future can achieve.

The Coalition for Reimagined Mobility (ReMo) believes in the potential of a 21st century mobility system to fundamentally improve people's lives. A multimodal mobility system that prioritizes people, the planet, technology, security, individual choice, economic productivity, human flourishing, and global competitiveness. ReMo also recognizes that a reimagined mobility system will look different across the world and even within countries, involving different sized vehicles, different services, different needs and different expectations. Yet there are common ingredients of what is critical to realizing a reimagined mobility system for the 21st century and beyond.

A reimagined mobility system meets transportation needs in a timely, safe, reliable, and cost-efficient manner for both personal mobility and goods delivery. It is a system that dramatically curbs the global transportation sector's reliance on oil and contributions to environmental harm, eliminates unnecessary trips, provides increased freedom and choice, and addresses inequities throughout the current system.

This mobility system centers on the reality that one size does not fit all, and that the mix and application of solutions required will vary by location, context, and personal preference. These solutions will be successful because of their ability to tap into a convergence of trends: ubiquitous connectivity, seamless automation, more powerful sensors, expanded electrification, and powerful applications of data and analytics. In this mobility system people will be able to select the transportation option that works best for them, while minimizing or eliminating the many inefficiencies present in the current system.

In a reimagined 21st century mobility system, time is not wasted on waiting for your ride to arrive. Oil is not burned unnecessarily on empty freight miles or inefficient vehicle use. Unnecessary emissions do not pollute the air. Lives are not unnecessarily lost to crashes on the roadways. Dollars are not wasted on projects and systems that fail to effectively meet public needs or deliver intended outcomes. Those economically disadvantaged, underprivileged communities and people with disabilities do not face burdens to accessing or paying for their transportation options.

ReMo also believes that this mobility future is unlikely to manifest organically, and instead will require radical thinking, and

unprecedented coordination, and commitments to deliver. While a multitude of innovative technologies and disruptive solutions have emerged in the transportation sector in recent decades, the challenges that the creators of these technologies set out to address have in some cases become more pronounced: climate change has continued to progress, oil demand has continued to rise, road fatalities have continued to climb, and transportation has become even less affordable for those who benefit most from the opportunity it offers.

*A **successful 21st century mobility system** will support a user choosing the mode that best fits their current needs.*

8 HARD TRUTHS

To take the bold action necessary to address these challenges, ReMo believes there are eight hard truths that should be acknowledged.

1. There is no silver bullet

No individual technology or policy change will solve the world's transportation challenges, nor should that be the expected outcome. Instead, we should outline reasonable expectations for technology investment and appropriate timelines to deliver results. Similarly, we should not be so naïve as to prescribe a one-size-fits-all approach to mobility solutions. A reimagined mobility system will look very different in a densely populated European city, a bustling South Asian metropolis, or the suburbs of a mid-sized North American city.

2. Technology is a force multiplier

While there are no silver bullet solutions, there are tremendous systems benefits that come with the joint deployment of new mobility technologies and services. Vehicle automation stands to make electrification more compelling. Vehicle connectivity makes automated driving systems more effective while also saving lives with non-fully automated technology like driver-assistance. Data from connected vehicles allows planners to make more informed decisions about road design. All these technologies together will make on-demand point-to-point transport of people and goods cleaner, safer, more affordable, and convenient. Supporting a host of technologies and approaches to reimagining a mobility system offers the greatest gains and most transformative impact.

3. Successful mobility solutions are human-centered, not vehicle-centered

Reimagining today's transportation systems must start with the question: how do we better meet the mobility needs of a population? This means centering on users and prioritizing the mobility offerings, vehicle designs, and technology integration that improves access, quality, and reliability of transportation. This human-centered approach requires a deep understanding of the geographic, cultural, and personal decisions that will dictate which solutions will be successful and adjust strategies to meet the needs of the user.

4. Extensive public and private sector coordination and alignment

To effectively test, deploy, and scale necessary and new mobility solutions, the public and private sectors must work closely together. This means coordination on the policies required to deploy innovative new technologies, agreement on what challenges need to be solved, alignment on how success will be measured, and collaboration to preempt and address blockers where they emerge. Note that this does not only mean coordination of the public sector with the private sector, but also the coordination within government (e.g., city leaders with national policymakers, departments of energy with departments of transportation, transit agencies with housing authorities, etc.) as well as between private sector stakeholders (e.g., automated vehicle operators with battery manufacturers, long-haul freight carriers with port terminals, bikeshare operators with mobility as a service providers, etc.). This coordination must start as early as possible, needs to include a broad set of stakeholders, and should be regularly revisited to be effective.

5. A diverse range of mobility options increases consumer choice

New technologies and innovative approaches to mobility must be considered in the context of where, when, and for whom they are needed. What works for one person in one area may not work for another. A family of four in a suburban setting dealing with school drop-offs in the morning has different mobility needs than a couple going out to dinner in the city, or for the freight carrier handling the middle-mile of a package delivery schedule. A successful 21st century mobility system will support a user choosing the mode that best fits their current needs. In some cases, this will be a personally owned electric vehicle for family travel, in others it will be a shared-use vehicle deployed in a transit capacity for an individual commute, or a convenient micromobility device on multimodal-appropriate infrastructure to get to a doctor appointment, or an automated commercial truck to move goods safely and more efficiently across the country or deliver a package to the door. In each of these cases, user needs are matched with the mobility option that meets their needs while minimizing emissions, cost, and risk.

6. Policy changes are only a first step

While changes to public policy will be needed to effectively test, deploy, and scale new mobility technologies and services, policy is not the sole or only blocker to realizing a reimagined mobility future. To deliver a reimagined mobility system, one must also consider challenges of consumer acceptance as well as underlying systemic challenges that have or will limit the impact of novel technology solutions. These challenges include workforce development, vulnerable supply chains, outdated liability structures, insufficient public infrastructure, a hyperfocus on quarterly earnings reports, political polarization, and culture wars about transportation choices, among other things. Leadership is essential to address these non-policy blockers and overcome existing inertia and will require coordinated action across industries and include a diverse set of stakeholder perspectives at the proverbial table.

7. Charting a long-term vision requires executing short-term actions

Aspirational long-term goals are essential to realizing a reimagined mobility system while equally ensuring we do not settle for incremental improvements that fail to fully realize the potential of new technologies. At the same time, we can't be so exclusively focused on long-term goals that we fail to take the near-term steps required to make progress toward these goals. Stakeholders should establish a clear vision that includes metrics and milestones and that sets out bold, aspirational goals but also establishes what immediate actions should be prioritized to make progress toward this end state.

8. In some cases, meeting mobility needs can mean eliminating the need to travel

While many transportation innovations focus on making travel more efficient, safer, cheaper, and cleaner, there is huge potential for new mobility technologies to meet some user needs without the need for physical travel. This can include virtual access to essential services including healthcare, finance, and education or the delivery of goods. This does not mean limiting people's freedom to move – it simply means removing burdensome, inconvenient trips and enhancing people's access to essential services and opportunities.

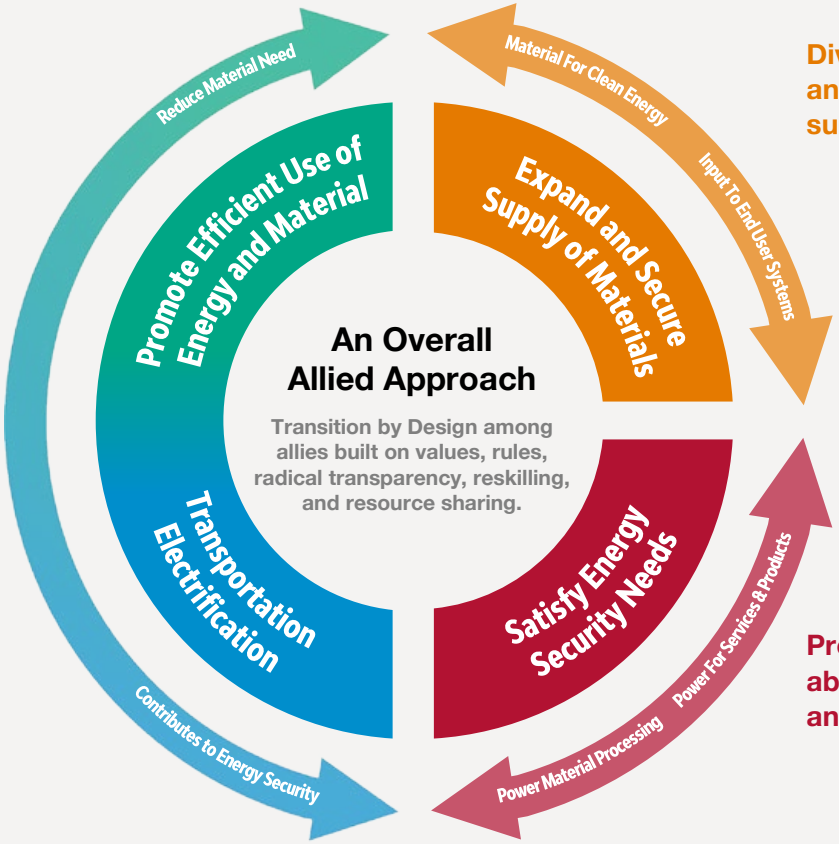
As part of SAFE, ReMo believes that no single technology or policy will solve our mobility challenges and that a systems approach is required to achieve systems-level benefits.

Just as the power sector is adapting to the global energy transition, the transportation sector – now the leading source of greenhouse gas emissions and air pollution and a sector still almost entirely dependent on oil – must commit to its own transformation. The ultimate delivery of a 21st century mobility system will only be successful by convening the necessary stakeholders across the public and private sectors to collaborate and accelerate this transformation to ensure a reimagined mobility future that is sustainable, accessible, flexible, efficient, and resilient.

Figure 2. SAFE's Overall Allied Approach.

Put people first, providing what they need for where they need to go affordably, cleanly, safely, and efficiently

Diversify secure and responsible supply



Develop and implement the policies and actions to accelerate electrification at scale

Provide clean, abundant, affordable, and reliable energy

How We Got Here

Today's reality was driven by yesterday's history: new policy, technology, competition, and a desire for freedom. The automobile was first invented and perfected in Germany and France in the late 1800s, though the United States soon came to dominate the automotive industry in the first half of the twentieth century. It was a key force for change. The automobile revolutionized personal freedom and how all people could move around and interact with one another.

In the United States, affordable, widely available cars gave people unparalleled access to jobs, services, and social activities on their own schedules, while stimulating the economic growth of ancillary industries – particularly steel, petroleum, tourism, and public works construction.

In 1900, there were roughly 8,000 registered automobiles in the United States.[43] Paved roads were few and far between and gas stations had yet to become the fixtures that exist today. Instead, motorists purchased gasoline from pharmacies and blacksmiths and wedged their cars into makeshift parking spaces among horse drawn carriages tied to hitching posts.

Shortly thereafter, the First World War accelerated the shift from getting around on horseback to using a motor vehicle. The U.S. automobile industry played a critical role in producing military vehicles during the war, retooling production to also include tanks and planes.[44]

By the 1940s, the U.S. automobile industry was serving both civilians and the military. It continued to supply vehicles for the nation's growing car culture, all while increasing production of vehicles for the wartime government and dramatically broadening their output to include military weapons such as tanks, engines, cannons, trucks, and aircraft to serve a massive Allied build-up. When the war ended, there were roughly 31 million registered vehicles in the United States.[45]

Then by the dawn of the 1960s, that number had increased to nearly 74 million registered vehicles.[46] The birth of suburbs, the interstate highway system, and the prevalence of the automobile in the country's postwar years changed American life forever.

By 1970, the exponential growth in engineering, government expenditures, and business ingenuity had led to new vehicle design, roadway-specific infrastructure, energy supply, gasoline taxes, and parking policies that all converged to

[43]Federal Highway Administration. (1997). State Motor Vehicle Registrations By Years 1900-1995.
[44]George, A. The Iconic WWI Vehicle That Paved the Way for Modern Cars. (2014, July 28). Wired.
[45]Federal Highway Administration. (1997). State Motor Vehicle Registrations By Years 1900-1995.
[46]Ibid.

Gas shortage sign, Connecticut, 1974

cement the automobile as the backbone of a U.S. transportation system and offered unprecedented access to on demand, private transportation.

The U.S. and European auto manufacturers dominated market share, ownership of intellectual property, and strength of industrial know-how. Along with transformative mobility benefits, the automobile and system also resulted in the sector's heavy dependence on oil, rising levels of air pollution and traffic fatalities.

Today in the United States there are around 275 million registered vehicles,[47] 2.8 million miles of paved roads,[48] 145,000 gasoline stations,[49] and an estimated six parking spaces for each vehicle.[50] Ninety-two percent of U.S. households own at least one car and 22 percent own three or more.[51] Americans drive personal cars over three trillion miles annually,[52] yet use them just five percent of the time.[53]

What drove the enormous growth in automobile transportation? Why do Americans today pay on average nearly $50,000 for new cars and $25,000 for used cars and then park them 95 percent of the time?[54] Answers to these questions provide essential insight into the requirements of a new mobility system that is safer, more sustainable, more secure, and more efficient while still offering the freedom to move that people have come to expect.

The growth of the U.S. auto industry and associated policy

The U.S. auto industry grew rapidly between 1900 and 1970 as a largely unregulated, interdependent system of motor vehicles and industrial materials production – specifically steel and petroleum. It also included highways, streets, and parking infrastructure, enabled by democratic capitalism, and enriched by American advancements in engineering and an increase in consumer demand and consumer wealth.

Positive user feedback toward this system accelerated this growth. More cars led to more middle-class jobs, which meant more people had more money to buy more cars. More cars led to more gasoline tax revenue which led to more – and better – roads, which led to more cars. More cars led to more parking and gas and service stations, which led to more cars. By 1970, these feedback loops resulted in Americans driving 110 million cars 1.5 trillion miles annually on 1.6 million miles of paved roads consuming around 90 billion gallons of gasoline purchased

[47]See Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances in United States. Department of Transportation. Bureau of Transportation Statistics. (2019). National Transportation Statistics (NTS).

[48]Ibid, Public Road and Street Mileage in the United States by Type of Surface.

[49]American Petroleum Institute. (n.d.). Service Station FAQs. www.api.org/oil-and-natural-gas/consumer-information/consumer-resources/service-station-faqs

[50]See for example Baldwin Hess, D., & Rehler, J. (2021, June 15). America has eight parking spaces for every car. Here's how cities are rethinking that land. Fast Company.; Harrison, D. (2023, April 2). America Has Too Much Parking. Really. Wall Street Journal. and Litman, T. (2022). Comprehensive Parking Supply, Cost and Pricing Analysis. Victoria Transport Policy Institute.

[51]Tilford, A., & Megna, M. (2023, September 12). How Many Vehicles Are There In The U.S.? Forbes Advisor.

[52]Chart VMT-421C - Highway Statistics 2019. (2019). Federal Highway Administration.

[53]National Household Travel Survey Daily Travel Quick Facts. (2017). Bureau of Transportation Statistics.

[54]Siegel, R., & Whalen, J. (2023, May 8). New cars, once part of the American Dream, now out of reach for many. Washington Post.

at 200,000 gas stations[55] and leading to the creation of 500 million parking spaces.[56] However, automobiles led to smog in cities, rising traffic-related deaths, an increasing dependence on autocratic countries for fuel, and growing lead pollution. These negative externalities made it all too clear to users the price of the freedom that came with automobiles.

During the 1970s, the United States government took its boldest action to date, establishing policies and new government agencies to address the negative externalities of automobiles and the sector's dependence on oil, while also determining significant motor vehicle safety, fuel economy, emissions, and unleaded fuel regulatory standards. The National Highway Safety Bureau (NHSB) introduced landmark automobile safety regulations from the late 1960s onwards, including updates and requirements for safety glass, braking systems, standard seat belts, door latches, lighting, child vehicle restraints, and vehicle impact and safety testing.

The National Highway Transportation Safety Administration (NHTSA) was officially established in 1970 by the Highway Safety Act, succeeding the NHSB. The agency was tasked with reducing deaths, injuries, and economic losses from motor vehicle crashes. NHTSA was also given the power to issue vehicle recalls. The Clean Air Act was also enacted in 1970, which required a 90 percent reduction in emissions from new automobiles by 1975. Simultaneously, U.S. President Richard Nixon established the Environmental Protection Agency (EPA) and gave this new agency wide discretion in setting regulations on motor vehicle pollution. The 1973 oil crisis caused by the Arab-Israel war and the Organization of the Petroleum Exporting Countries (OPEC) oil embargo prompted the Energy Policy and Conservation Act, which lead to the introduction of Corporate Average Fuel Economy (CAFE) standards in the late 1970s on passenger vehicles and light trucks. The transportation policy activity of the 1970s has served as the foundation of U.S. transportation policy and has shaped the entire transportation system to date.

These bold policy actions began to meaningfully address air pollution, safety, and efficiency challenges in the U.S. transportation system. A comprehensive assessment in 2020 of the historical impact of the CAFE standards found that they saved $5 trillion in fuel costs and prevented 14 billion metric tons of carbon from being released into the atmosphere – which is the equivalent of the United States eliminating its emissions from all sectors for nearly three years.[57] According to the EPA, between 1970 and 2020 the combined emissions of the six most common pollutants (PM2.5 and PM10, SO2, NOx, VOCs, CO and Pb) dropped by 78 percent.[58] Between

Historical Impact of CAFE Standards

$5 TRILLION

saved in fuel costs

14 BILLION

tons metric carbon prevented from being released into the atmosphere

Source: Andlinger Center for Energy and the Environment

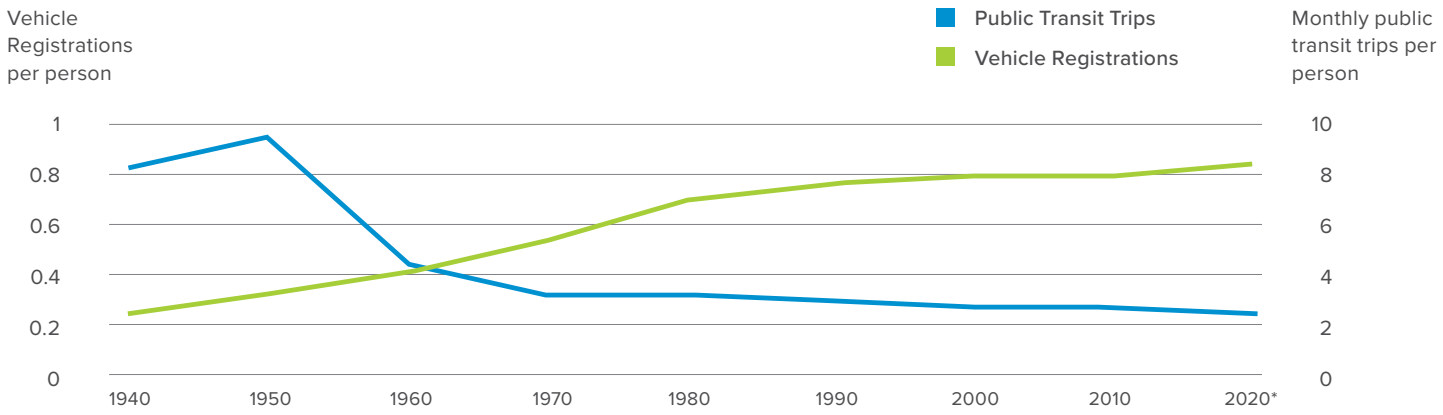
[55]Lienhard, J. H. (n.d.). The Engines of Our Ingenuity: Gas Stations. University of Houston.

[56]See Total Population, Motor-Vehicle Registration and Motor Fuel-Consumption in United States. Federal Highway Administration. (1971). Highway Statistics 1970. Federal Highway Administration. p 39. The United States government has never and does not currently track the number of parking spaces available in the United States. University of California, Los Angeles professor of urban planning and parking researcher Donald Schoup estimates that there are roughly 2.5 to 7 parking spaces per registered vehicle in the United States. Using this range to arrive at a moderate estimate of 4.5 spaces per registered vehicle, this leads to a calculation of 500 million parking spaces in 1970. See Harrison, D. (2023, April 2). America Has Too Much Parking. Really. Wall Street Journal.

[57]See U.S. fuel economy standards study show big savings on fuel and emissions. (2020, August 25). Andlinger Center for Energy and the Environment and Greene, D. L., Greenwald, J. M., & Ciez, R. E. (2020). U.S. fuel economy and greenhouse gas standards: What have they achieved and what have we learned?. Energy Policy, 146, 111783.

[58]U.S. EPA. (2015, June 8). Progress Cleaning the Air and Improving People's Health. United States Environmental Protection Agency.

Figure 3. US Registered Vehicles and Transit Usage Over Time.



Source: ReMo analysis based on data from U.S. Census, American Public Transportation Association, and Federal Highway Administration

1966 and 2014, the highway fatality rate in the United States dropped from 5.5 to 1.1 deaths per 100 million vehicle miles travelled, despite a population increase of 62 percent and a tripling of vehicle miles travelled (from 926 to 3,026 billion miles).[59] The harmonized National Program for fuel efficiency, jointly administered by NHTSA, the EPA, and the California Air Resources Board (CARB) is expected by 2030 to result in oil savings of more than 3 million barrels per day, roughly equivalent to U.S. oil imports from both the Persian Gulf and Venezuela combined.[60]

On the margins: the role of transit in the U.S.

During the 20th century, public transit in the United States decreased in popularity and ridership as it struggled to compete with the unparalleled ease and convenience that was offered by the automobile. With the investment in the U.S. highway and road network and the growth of suburbanization in large parts of the country, it was difficult for fixed-route transit to compete and supply adequate service over sizeable geographic areas. Levels of transit ridership are impacted by transit service frequency, fares, service reliability, gas prices and socio-economic and demographic trends.[61] In the United States, the sum of these factors has made the automobile the most logical transportation choice for Americans who are able to drive and can afford their own vehicle. Poor execution of franchised service operations meant that most transit services ended up in public ownership by the mid-20th century. Between 1950 and 1980, transit's inflation-adjusted operating costs rose 183 percent.[62] Meanwhile, transit ridership had

[59]See United States. Department of Transportation. Bureau of Transportation Statistics. (2019). Passenger Travel Facts and Figures. As at late 2022, the fatality rate stands at 1.30 fatalities per 100 million vehicle miles traveled, down from the projected rate of 1.32 fatalities during the same time in 2021. NHTSA Estimates for First Nine Months of 2022 Suggest Roadway Fatalities Beginning to Level Off After Two Years of Dramatic Increases. (2023, January 9). National Highway Traffic Safety Administration.

[60]A Brief History of U.S. Fuel Efficiency. (2006). Union of Concerned Scientists.

[61]Erhardt, G. D., Hoque, J. M., Goyal, V., Berrebi, S., Brakewood, C., & Watkins, K. E. (2022). Why has public transit ridership declined in the United States? Transportation Research Part A: Policy and Practice, 161, 68–87.

[62]Costs are inflation-adjusted per revenue bus-hour. Kim, S. (2005). The Effects of Fixed-Route Transit Service Contracting on Labor. University of California Transportation Center, Working Paper.

collapsed by 50 percent during that period while private automobile numbers tripled.[63]

Ultimately, Americans faced a choice about how they wanted to get around – and in most parts of the country, Americans chose overwhelmingly the personal freedom offered by the automobile. By the 1970s and 80s, only 3 percent of all trips in urban areas were made by bus, subway, streetcar and commuter rail.[64] Monthly transit trips dropped from a high of over 9 trips per capita in 1950 to 2.5 trips per capita in 2018. In 2023, around 1.3 percent of all trips in the United States are made using some form of public transit.[65]

Given that over generations, so few Americans outside of dense cities like New York have had the experience of regularly using transit compared to people living in European or Asian cities – it is understandable why there has been greater political and policy support in the United States for motor vehicles and related infrastructure investments than for traditional transit investments. Indeed, over half of all U.S. transit agencies report that they will face a severe operating budget fiscal cliff in the next five years.[66] Efforts from the 1980s onwards to stimulate service contracting, a commonplace public-private partnership practice outside the United States for improving the efficiency and service quality of transit, have largely been unsuccessful.[67] Transit services remain a transportation lifeline to those who cannot operate or cannot afford to own a car in the U.S., and transit is the backbone of mobility systems in many cities globally. However, transit authorities and operators around the world are being forced to adjust to structurally lower ridership and thus lower fare revenues due to changed mobility behavior post the COVID-19 pandemic and people's desire for greater flexibility.[68] These changes are necessitating a rethink of sustainable economic models for public transit operations.[69] U.S. fixed route transit in general continues to face significant cost efficiency[70] and public acceptance challenges.

Foreign competition disrupts the U.S. auto market

As described already, in the 1970s, U.S. automakers were forced to respond to a new regulatory landscape that sought to tackle the social and economic costs of increased air pollution, and declining oil reserves, as well as mounting safety concerns of its motor vehicle centric transportation system. Automakers did this by transitioning passenger vehicles

1970s Toyota Corolla

[63]See Suburban Sprawl: Private Decisions and Public Policy. (n.d.). and Burchell, R. W., Lowenstein, G., Dolphin, W. R., Galley, C. C., Downs, A., Seskin, S., ... & Moore, T. (2002). Costs of sprawl--2000 (No. Project H-10 FY'95).

[64]Pucher, J. (1988). Urban Public Transport Subsidies in Western Europe and North America. Transportation Quarterly, 42(3), 377–402. p 378

[65]This figure is derived from a calculation comparing Bureau of Transportation Statistics figures from March 2023 which show that Americans took 1.6 billion trips per day, with American Public Transportation Association figures from March 2023 which estimated there to be around 604 million unlinked transit trips in that month (equating to roughly 20 million daily transit trips). See Daily Travel. (n.d.). Bureau of Transportation Statistics. and Kahana, D. (n.d.). Public Transportation Ridership Report First Quarter 2023. American Public Transportation Association.

[66]APTA: Public Transit Agencies Face 'Severe' Fiscal Cliff. (2023, June 14). Railway Age.

[67]For a background on service contracting, and lessons from international experience that could apply to the United States, see TransitCenter & Eno Center for Transportation. (2017). A Bid for Better Transit: Improving service with contracted operations.

[68]What does 'new normal mobility' look like? (2023). International Association of Public Transport (UITP).

[69]Ibid.

[70]Goldwyn, Eric, Alon Levy, Elif Ensari, and Marco Chitti. 2023. "Transit Costs Project Executive Summary." New York City, NY: New York University Marron of Urban Management.

Credit: © https://www.flickr.com/photos/charliecars/

from rear-wheel drive body-on-frame to front-wheel drive body-frame-integral architectures, but U.S. manufacturers had challenges making this transition smoothly.

At the same time, Japanese manufacturers entered the U.S. market on a large scale, setting industry benchmarks for quality, productivity, and fuel economy.[71] Japanese manufacturers, much like Chinese auto manufacturers today, benefited from generous government subsidies in the 1950s and 1960s as well as access to a reliable supply of crucial materials such as steel and machinery.[72]

By the early 1980s, Japanese cars had become so popular in America that the Japanese Ministry of International Trade and Industry (MITI) had put in place a Voluntary Restraint Agreement (VRA) to limit the amount of auto exports Japan shipped to the United States. This restraint agreement was implemented by the Japanese government under extreme pressure from the Reagan administration, which was attempting to mitigate the severe economic downturn faced by the American auto sector and its unions following the 1970s oil crisis and the failure of manufacturers to pivot towards more novel, efficient motor vehicles that were popular with consumers.[73]

In addition to the formidable competition that U.S. automakers faced from Japanese auto manufacturers from the 1970s onwards, Korean auto companies entered the U.S. market in the 1990s with impressive quality, reliability, durability, and designs. By the 21st century Toyota, Honda, Nissan, Hyundai, and Kia had ended the General Motors (GM), Ford, and Chrysler oligopoly, eroding the Big 3's market share in the United States from 85 percent in 1970 to 44 percent in 2010.[74]

A Global Financial Crisis and the dawn of disruptive transportation technologies

The late 2000s presented another existential crisis, to which U.S. auto manufacturers, as well as their suppliers and dealers, were especially vulnerable. When the 2008 financial crisis hit, liquidity froze in the financial markets. These unprecedented events triggered the Great Recession and caused U.S. auto sales to plummet nearly 40 percent from 17 million in 2006 to 10 million in 2009.[75] To make matters worse, the price of oil spiked to a record high of $150 per barrel in 2008,[76] which significantly impacted sales of highly profitable large pick-ups and sport utility vehicles (SUVs) that now made up an important share of vehicle sales.[77] When oil prices rose, these vehicles became less appealing and less affordable for consumers resulting in automakers offering hybrid electric vehicles, such as the Toyota Prius, to gain more of a market share.[78]

The U.S. auto industry nearly collapsed with potentially devastating nationwide implications given its far-reaching and deep tentacles throughout the economy. Had the U.S. government not engineered a rescue package via the Troubled Asset Relief Program, it is likely that tens of thousands of jobs would have been lost and real estate markets as well as hundreds of related businesses would have been impacted.[79] While this collapse was avoided, it resulted in a massive working capital[80] effect of 40 percent lower production combined with a complete lack of liquidity to borrow capital in the market. The bankruptcy of GM and Chrysler was precipitated by a situation where sales and share values were collapsing and market financing was unavailable, in the context of an external economic black swan event and rising oil prices. Notably, Ford avoided bankruptcy because, prior to the liquidity crisis,

[71]Boers, J. (2020). The Keiretsu Advantage: How Japanese Automakers Thwarted American Competition. 1.

[72]Ravina, M. J. (2022, May 15). When the Japanese Auto Industry Flooded the U.S. Market in the 1970s. Wondrium Daily.

[73]Cohen, S. D. (n.d.). The Route to Japan's Voluntary Export Restraints on Automobiles. National Security Archive.

[74]Perry, M. (2019, June 28). Market shares of U.S. auto sales, 1961 to 2018. American Enterprise Institute - AEI.

[75]IEA. 2020. "Global Car Sales by Key Markets, 2005-2020 – Charts." IEA. May 2020.

[76]Bolton, Paul. 2022. "Oil Prices," November 2022; U.S. Energy Information Administration. 2023. "U.S. Crude Oil First Purchase Price (Dollars per Barrel)." September 2023.

[77]Dupor, Bill, Rong Li, Saif Mehkari, and Yi-Chan Tsai. n.d. "The 2008 U.S. Auto Market Collapse."

[78]Li, Shanjun. 2009. "What Motivates People to Buy Hybrids?" Resources for the Future. November 2009.

[79]Littman, David. 2012. "What If Taxpayers Hadn't Bailed Out GM and Chrysler? - DBusiness Magazine." DBusiness, September 2012.

[80]Note: Working capital is a measurement of a company's short-term financial health, based on a calculation of a company's current assets divided by its liabilities.

[81]Electrification Coalition. 2009. "Electrification Roadmap." Washington, D.C.: Electrification Coalition.

Sandstorm before the 2004 DARPA Grand Challenge qualifying run.

it had raised funds by mortgaging its brands in anticipation of massive operating losses in its ongoing business.

From 2000 to 2010, a new design template for roadway transportation began to emerge. The 110-year-old age of automobiles started to give way to a new age of mobility based on the emergence of connected, electric, and autonomous, vehicle technology, and new innovative business models. This wave was arguably marked in 2006 with the unveiling of the Tesla Roadster, a niche electric performance sports car that turned the traditional notion of EVs as "dinky" city cars upside down.[81] This vehicle was the canary in the coalmine of the promise and customer appeal of lithium-ion battery-powered electric vehicles with outstanding performance. The introduction of General Motors' Volt concept the next year added credence to the idea that vehicle electrification was becoming possible. Both vehicles captured the public's attention, adding a cachet that electric powered vehicles previously did not possess.[82]

Vehicle connectivity, historically known as telematics, also began to develop at an accelerated pace. GM pioneered the modern telematics industry with the launch of the OnStar system in 1997. As cell phones were still relatively rare during this time, the primary purpose of this system was to serve in case of emergencies – though the potential navigation and driver assistance functions were also recognized.[83] However, with the rise of software as a service, cloud computing and common technical interfaces in the 2010s, third party operators such as TomTom were able to begin offering advanced and high-speed connected vehicle services.[84] Component manufacturers such as Qualcomm have become a critical supplier to the automotive industry of not only traditional telematics technologies such as positioning, but also advanced 4G and 5G, C-V2X, wireless internet and Bluetooth connectivity hardware, software, and services.[85] The value of connected car data has been predicted by McKinsey to be as large as $750 billion by 2030.[86]

In terms of autonomous vehicle technology, by 2009 Google had secured the skills of the brightest engineering talent from the U.S. Department of Defense R&D brand, the Defense Advanced Research Projects Agency (DARPA) autonomous vehicle challenges. DARPA birthed the Internet and the satellite navigation systems commonly used in smartphones.[87] DARPA's autonomous vehicle competitions, such as the Grand Challenge and the Urban Challenge,[88] greatly accelerated the development of autonomous vehicle technology. Sebastian Thrun, the leader of Stanford's team that won the 2005 Grand Challenge, went on to found Google's autonomous car project, now known as Waymo.[89]

In the early 2010s an evolved concept of ridehailing as part of the future of mobility emerged alongside the growth of mobile

[82]ibid

[83]Tate, James. 2023. "What Is OnStar and How Does It Work?" Capital One Auto Navigator (blog). February 7, 2023.

[84]TomTom Telematics. n.d. "A Brief Guide to the History of Telematics." Accessed September 29, 2023

[85]Qualcomm. n.d. "Automotive Telematics Systems." Accessed September 29, 2023.

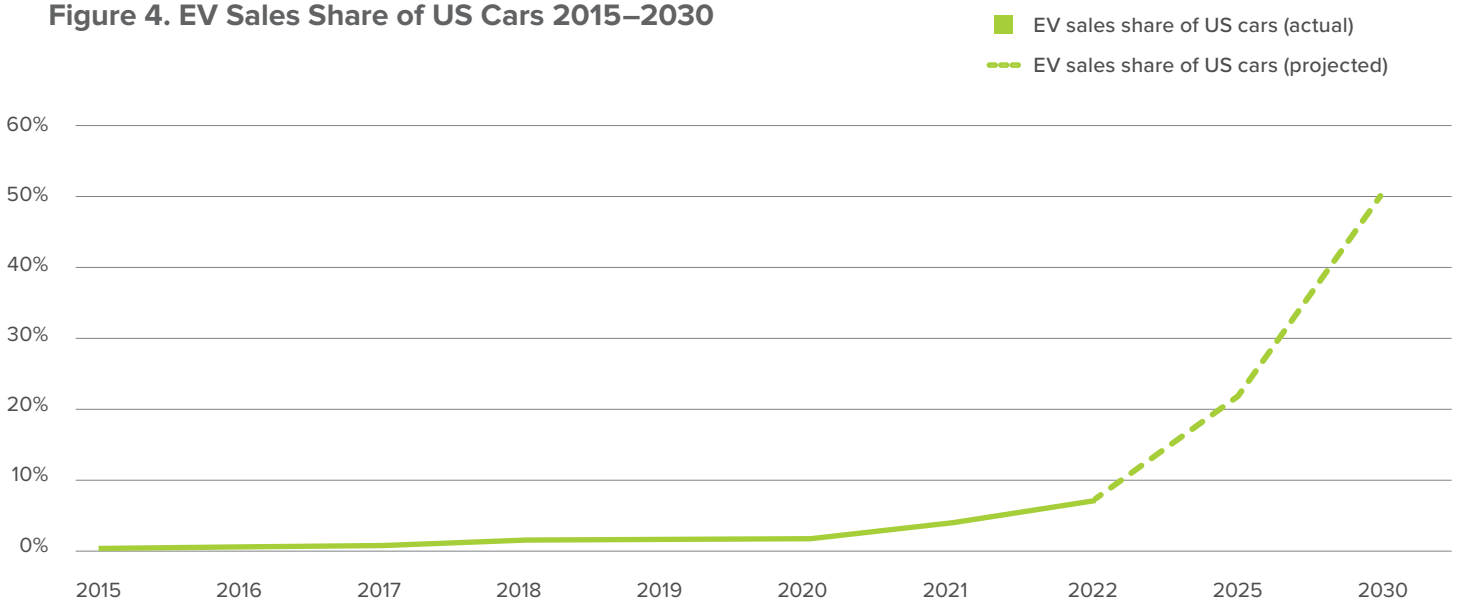
[86]Dharani, Shafiq, Tom Isherwood, Diego Mattone, and Paolo Moretti. 2018. "Telematics: Poised for Strong Global Growth." McKinsey and Company, April 2018.

[87]See, e.g., Interview with Regina Dugan and Walt Mossberg, "Defense on the Offense," The Wall Street Journal, June 6, 2011.

[88]Urmson, Chris, Joshua Anhalt, Drew Bagnell, Christopher Baker, Robert Bittner, M. N. Clark, John Dolan, et al. 2008. "Autonomous Driving in Urban Environments: Boss and the Urban Challenge." Journal of Field Robotics 25 (8): 425–66.

[89]Markoff, John. 2010. "Google Cars Drive Themselves, in Traffic." The New York Times, October 9, 2010, sec. Science.

Figure 4. EV Sales Share of US Cars 2015–2030



Source: ReMo analysis based on IEA data.

technology and GPS systems, providing people with a new way to spontaneously travel directly from point-to-point without having to own and drive a car, that also was not a traditional taxi service. Zimride, which later evolved into Lyft, started as a long-distance carpooling service in 2007. The Uber app, launched in 2010, popularized the concept of "ridehailing" where users could book rides from drivers using their personal cars. It was first tested in New York and then officially launched in San Francisco. Ridehailing companies have made various forays into automated vehicle deployment, specifically because of the great potential that autonomous vehicle technology has to expand the service area and reliability of ridehailing as well as reduce operational costs by removing the need for a human driver.[90] The immediately recognized benefits of ridehailing included reducing the inconvenience of finding parking and preventing unsafe behaviors such as impaired driving.[91]

These important automotive and technology advancement milestones all occurred during the darkest days of the auto industry, and during the Great Financial Crisis. While GM and Chrysler were going bankrupt and other automakers were fighting for their lives, technology-driven companies from outside the industry were planting the seeds of a new mobility revolution. These new players in transportation possessed a deep understanding of digital technology, connectivity, and a passion for designing and delivering compelling mobility experiences – not just attractive cars.

Today's Mobility Inflection Point

Today, several tipping points have been reached in new mobility technologies. These tipping points enhance people's freedom to live their lives and have the mobility services they need while providing greater efficiency and sustainability benefits.

Electric vehicles sales are at a tipping point, globally and in the United States. A 2022 survey showed that 52 percent of global car buyers want an electric vehicle, a growth of 22 percentage points in just two years.[92] Tesla's Model Y became the world's best-selling car – across all fuel types – during the first quarter of 2023 (with 267,000 sales).[93] Other automakers are betting big on EVs, with plans to put 100 EV models into the U.S. market for 2025.[94] EVs are expected to make up 22 percent of passenger vehicle sales in the United States by

[90]Benjaafar, Saif, Zicheng Wang, and Xiaotang Yang. 2021. "The Impact of Automation on Workers When Workers Are Strategic: The Case of Ridehailing." SSRN Scholarly Paper. Rochester, NY.; University of Minnesota Center for Transportation Studies. 2022. "Adding Autonomous Vehicles to Ridehailing Fleets Could Benefit Platforms and Drivers ." February 2022.

[91]Clewlow, Regina R, Gouri Shankar Mishra, Regina Clewlow, and Stephen Kulieke. n.d. "Disruptive Transportation: The Adoption, Utilization, and Impacts of Ridehailing in the United States."

[92]EY Global. 2022. "Tipping Point Reached as More than Half of Global Car Buyers Seek Electric Vehicle for the First Time." May 2022.

[93]Munoz, Juan Felipe. 2023. "Tesla Model Y Was The World's Best-Selling Car In Q1 2023." Motor1.Com. May 2023.

[94]Edelstein, Stephen. 2022. "Will an EV Shift in 2025-2035 Be the Most Transformative Period in the History of the Automobile?" Green Car Reports. April 11, 2022.

2025 and 50 percent by 2030, up from 7.7 percent in 2022.[95] This impressive projected growth can be associated in large part due to the incentives offered by 2022's major industrial policy package, the Inflation Reduction Act (IRA), which will enable a growth in EV vehicle supply due to strengthened domestic supply chains and incentives for producing EVs.

Advanced driver-assistance systems (ADAS) on vehicles have become nearly standard, offering automatic emergency braking, adaptive cruise control, lane keeping, and lane changing technologies to assist drivers with safer operation of the vehicle. These systems are evolving further to better leverage connectivity and enable vehicles to now sense the environment around them and communicate that information to other vehicles, infrastructure, and personal mobile devices.[96]

C-V2X communication capabilities, where information from sensors travels via high-bandwidth, low-latency, high-reliability links, create a pathway from connected to automated driving. Components of C-V2X communications including vehicle-to-vehicle (V2V) communications, vehicle-to-infrastructure (V2I) – such as cameras, traffic lights, lane markers and weather stations – vehicle-to-pedestrian (V2P), and vehicle-to-cloud (V2C) communication further enhance the capabilities of these tech-enabled safety systems such as ADAS and help keep vulnerable road users such as bicyclists, pedestrians, people using wheelchairs, children in strollers, passengers embarking and disembarking buses and trains, and other nonvehicle occupants safer while enabling greater mobility and environmental advancements and reducing the burden of driving tasks.[97]

The technical capabilities and capacities of vehicle connectivity have broken new boundaries recently. In 2023 Qualcomm announced its new wireless data modem specifically for automobiles, capable of delivering vastly higher 5G processing power at a reduced cost and with fewer components.[98] New vehicles are increasingly becoming software-defined, meaning that it is possible to deliver repairs, updates, and improvements via over the air firmware updates, using the vehicle's own wireless connection. A connected car today has the computing power of 60 to 80 computers on board.[99]

Wireless app-based vehicle services such as ridehailing and other forms of on-demand mobility have also now passed a tipping point. In the first quarter of 2023, 130 million people used the Uber app at least once per month.[100] By 2030, total revenues from ridehailing, licensed and unlicensed driver services of all kinds, and on-demand shuttle services could increase between $450 billion and $860 billion.[101]

And, while the autonomous vehicle industry progresses, next-generation autonomous vehicle technology for moving people and goods is fast approaching, and in some cases already being piloted in-market. Robotaxis and autonomous shuttles from companies including Waymo, Cruise, Beep, May Mobility, Baidu, and Pony.ai are increasingly common sights in cities, particularly in the United States and China, and being deployed to reduce traffic-related emissions in metropolitan areas, reduce single occupancy passenger transportation, and simultaneously expand more sustainable, efficient, comfortable, and affordable mobility options to all people.

ADAS and autonomous technology combined are also now making their way into private passenger vehicles. GM's new Ultra Cruise system will offer a full hands-free driving system on 2 million miles of U.S. roads, covering 95 percent of driving situations using cameras, short- and long-range radar, and a lidar sensor.[102] Revenue from robotaxis and robo-shuttles

Credit: Gatik AI Inc.

[95]IEA. 2023. Global EV Outlook. Global EV Data Explorer. April 26, 2023.

[96]U.S. Department of Transportation. n.d. "Vehicle-to-Pedestrian (V2P) Communications for Safety."

[97]Hearst Autos Research. 2020. "ADAS: Everything You Need to Know." Car and Driver. April 13, 2020.

[98]Qualcomm. 2023. "Qualcomm Raises the Bar for Connected Car Technologies with Next Generation Snapdragon Automotive 5G Platform." February 27, 2023. https

[99]Renault Group. 2023. "All There Is to Know about Software Defined Vehicle." April 24, 2023.

[100]Statista. 2023. "Monthly Number of Uber's Active Users Worldwide from 2017 to 2023, by Quarter." Statista. May 2023.

[101]McKinsey Center for Future Mobility. 2023. "Shared Mobility: Sustainable Cities, Shared Destinies." McKinsey and Company.

[102]Hawkins, Andrew J. 2023. "GM's Ultra Cruise Will Use Radar, Camera, and Lidar to Enable Hands-Free Driving." The Verge, March 7, 2023.

could reach more than $400 billion in 2030, depending on how the related regulations and technologies develop.[103]

In the freight sector, Gatik's autonomous trucks are already moving middle mile goods between businesses in Arkansas, Louisiana, Kansas, Texas, and Ontario, Canada.[104] Meanwhile, multinational automotive parts manufacturer Continental has partnered with autonomous vehicle technology company Aurora to develop scalable autonomous trucking systems for application throughout the United States.[105]

More than any other mobility innovation in human history, the automobile promised people the ability to go where they wanted, when they wanted, and with the people they wanted. It promised privacy even in public spaces. It represented, at least theoretically, unfettered access to jobs, recreation, and services. It became an extension of people's homes and a symbol of post-war freedom. Having a car nearby meant you could simply get in it and go without the restriction of fixed-route or inconvenient schedules, especially in locations where transit services were challenging or nonexistent. Viewed in that light, it makes sense why 92 percent of American households spend a lot of money to buy and maintain at least one vehicle.[106] Research has shown that Americans value this freedom annually at $11,197 on average – more than the American Automobile Association's (AAA) reported average annual cost in 2021 of owning and using a car of $9,282.[107]

Between 1980 and 2020, little occurred to change how people physically moved around, but substantial levels of innovation across digital technology and communications systems have transformed how people use their time. The digital age then emerged in the early 1980s and transformed information and communication systems and how people live. Today, the internet, mobile phones, personal computers, e-commerce, social media, video conferencing, and streaming are all significantly impacting whether, where, when, and how people travel, and where they work and live. They are eliminating trips, retiming activities, reshaping urban, suburban, and rural areas, and enabling more people to have more mobility options to choose from when engaging in activities.

In 1998, the National Science Board noted that "probably the most striking change in industrial R&D performance during the past decade is the service sector's increased prominence",[108] particularly software development. In the early 1980s, R&D performance by non-manufacturing industries in the United States made up less than 5 percent of total R&D performance. By 1990, this had increased to 25 percent.[109] The National Science Board reported that in 2022, R&D performance by non-manufacturing industries such as information and software providers and computer system design made up 42 percent of all R&D. In contrast, R&D in motor vehicles stood at just 4.9 percent.[110]

Because a motor vehicle is akin to freedom, the biggest competitive threat to an automotive company is not just another automotive company. Rather, it is how the digital age, and a new era of innovation will reshape whether and how people and goods move. The automotive industry must reimagine how vehicles fit within broader social and economic systems, not just the traditional roadway transportation system.

Ultimately, the convergence of and innovation across transportation, communications, and information technology represents a profound shift in the way society operates and how people choose to live their lives. It is this very transformation that highlights the critical opportunity for policymakers to shape the future of mobility. As stakeholders navigate this dynamic landscape, policymakers must recognize that their decisions will be instrumental in determining which nations and communities emerge as the winners in this new era. This is not merely about technological progress; it is about harnessing these advancements to foster a mobility future that is prosperous, inclusive, secure, and sustainable for all.

[103]McKinsey Center for Future Mobility. 2023. "Shared Mobility: Sustainable Cities, Shared Destinies." McKinsey and Company.

[104]Templeton, Brad. 2022. "Meet Gatik, Which May Be The Leader In Self-Driving Trucks By Attacking The Middle Mile." Forbes, December 23, 2022, sec. Transportation.

[105]Continental. 2023. "Continental and Aurora Partner to Realize Commercially Scalable Autonomous Trucking Systems." Continental. April 27, 2023.

[106]Most households (91.7%) had at least one vehicle in 2021, up from 91.2% in 2017. See U.S. Census Bureau 5-Year American Community Survey (2017-2021)

[107]Moody, Joanna, Elizabeth Farr, Marisa Papagelis, and David R. Keith. 2021. "The Value of Car Ownership and Use in the United States." Nature Sustainability 4 (9): 769–74.

[108]Science & Engineering Indicators—1998. (NSB 98–1) Arlington, VA: National Science Foundation.

[109]National Academies of Sciences, Engineering, and Medicine. 2000. Measuring the Science and Engineering Enterprise: Priorities for the Division of Science Resources Studies. Washington, DC: The National Academies Press.

[110]Figure RD-11 and Table SRD-2 in Research and Development: U.S. Trends and International Comparisons.

The State of Mobility

Scaling today's technology will enable advanced mobility innovation. The mobility industry is amid what has been described as a seismic transformation. This once-in-a-century revolution continues to be a groundbreaking and transformative journey, driven by a host of new technologies related to electrification, connectivity, and automation, experimental business models, consumer demand, and the expansion of commercial market pilots.

To complete the seismic metaphor, what is unclear is whether this transformation will simply rearrange the landscape or whether it can be harnessed to usher in a new era of improved outcomes.

The first several decades of the 21st century have been defined by the scaling of Autonomous, Connected, Electric, and Shared (ACES)[111] vehicles, evolving communications technologies, new Mobility-as-a-Service models, as well as novel vehicle form factors. Further it involves new ways of utilizing emerging technologies and the data they produce. This section details that landscape and presents an honest evaluation of the promise, current status, highlights and pitfalls to deployment at scale of these new technologies as they are being applied in the United States and offers pathways to achieving exponential gains.

In more recent years the future of mobility has continued to fold in new trends that might disrupt how we move people and goods with new emerging and enabling technologies from Artificial Intelligence (AI), blockchain, and robotics, to advanced data analytics, the Internet of Things, and more. These technologies bring the potential to transform, modernize, and reshape the advanced mobility landscape with unprecedented opportunities to accelerate and resolve wider societal challenges related to improved safety and system flexibility, greater security, improved access, and reduced environmental impact.

With much of road-based transportation in the United States dedicated to the movement of people, the lion's share of this section zeros in on the passenger applications of these groundbreaking technologies.[112] While the primary lens for discussion centers on personal mobility, it is essential to consider the multi-use nature of today's mobility systems and how these advanced mobility applications and implications also apply in the context of commercial goods movement.

[111]Umar Zakir Abdul Hamid. (2022). Autonomous, Connected, Electric and Shared Vehicles: Disrupting the Automotive and Mobility Sectors. SAE International.

[112]Vehicle Miles Traveled by Highway Category and Vehicle Type (n.d.) Bureau of Transportation Statistics.

Autonomous Vehicles

Autonomous vehicles (AVs) use technology to partially or entirely replace the human driver in navigating a vehicle from an origin to a destination while utilizing a combination of sensors, cameras, LiDAR, radar, and software to perceive their surroundings, and make real-time decisions to avoid road hazards and respond to traffic conditions.[113]

The concept of AVs (or "self-driving" or "driverless" cars) have captivated the imagination of the public since as early as the 1930s.[114] In the next century to follow the promise of AVs to fundamentally revolutionize the way people experience mobility and their broader value-add to society writ-large, has increasingly been the premise for all the investment, development, and testing by the automotive OEMs, suppliers, and new entrants such as tech companies and venture capitalists. Over the past decade this technology has seemed poised to finally go from science fiction to reality, with many predictions focusing on just how soon the technology would be ubiquitous. Driving this enthusiasm has been work by researchers to quantify the vast potential benefits for users, from improved road safety and reduced traffic congestion to greater access for the elderly and persons with disabilities, among others. Further sustaining the support for this technology is the expectation that AVs can also deliver health and environmental benefits – the use of shared AVs could result in an average 20 percent reduction in harmful carbon emissions and small particulate (PM2.5) emissions.[115] Transformational safety benefits have also proved possible – recent research by Waymo in partnership with reinsurance company SwissRe, based on real-world operational data, showed that AVs can credibly eliminate crashes causing bodily injury and reduce property damage claims by 76 percent.[116] This research compared Waymo's liability claims data with mileage- and zip-code-calibrated private passenger vehicle (human driver) baselines established by SwissRe, using data from more than 600,000 claims and over 125 billion miles of exposure between 2016 and 2021.[117] Another collaborative research effort compared collision rates between AVs and human-driven ridehailing trips and found 65 percent fewer collisions when comparing a million driverless miles to ridehailing trips driven by a human driver.[118]

Following a surge in AV enthusiasm and investment in the early 2010s, when the narrative was that AVs were just around the corner, there has been a growing public sense that the technology has been slower to progress than anticipated. This has come even as companies have continued to deploy purpose-built vehicles in increasingly complex and expansive settings in both passenger and commercial applications. Contributing to this sense of letdown has been reports of companies that have folded due to lack of funding or pulled the plug on fully autonomous vehicle development to focus on related advanced driver assistance technologies while they re-strategize their approach to bringing AVs to market.

AVs Reduce **Collision Risks**

AVs reduce collisions by **65%**

AVs reduce property damage claims by **76%**

Source: Lillo, L. D., Gode, T., Zhou, X., Atzei, M., Chen, R., & Victor, T. (n.d.). Comparative Safety Performance of Autonomous- and Human Drivers: A Real-World Case Study of the Waymo One Service.

[113]Anderson, James M., Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, and Tobi A. Oluwatola. 2016. "Autonomous Vehicle Technology: A Guide for Policymakers." RAND Corporation.

[114]Snyder, J. (n.d.). 1939's 'World of Tomorrow' Shaped Our Today. Wired.

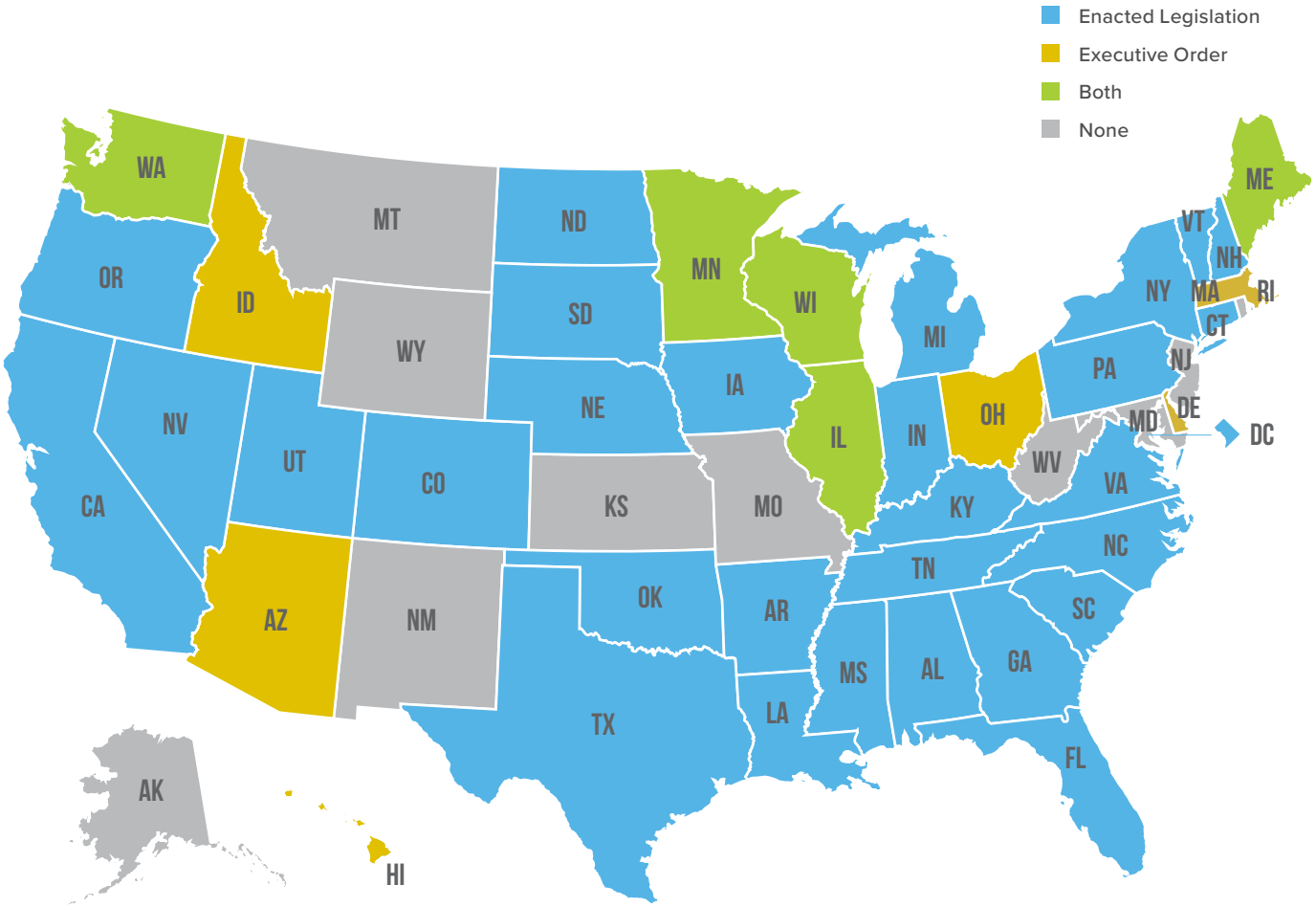
[115]Lempert, R. J., Preston, B., Charan, S. M., Fraade-Blanar, L., & Blumenthal, M. S. (2021). The societal benefits of vehicle connectivity. Transportation Research Part D: Transport and Environment, 93, 102750.

[116]Lillo, L. D., Gode, T., Zhou, X., Atzei, M., Chen, R., & Victor, T. (n.d.). Comparative Safety Performance of Autonomous- and Human Drivers: A Real-World Case Study of the Waymo One Service.

[117]Ibid

[118]Zhang, Louise. (2023). "Human Ridehail Crash Rate Benchmark." getcruise.com/news/blog/2023/human-ridehail-crash-rate-benchmark/.

Figure 5. Mapping AV On-Road Deployments Across the United States.



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, based upon the National Conference of State Legislators, Autonomous Vehicle Legislative Database, available at http://www.ncsl.org/ as of August 2020.

This has culminated in the recent backlash to AVs in some markets, which has even included physical violence against vehicles in some instances.[119]

Despite the rhetoric, the facts paint a different, more steady progression of AVs to market in the United States. To date, $160 billion[120] has been invested in AV technology in the United States to research, develop, test, and deploy autonomous vehicles. These investments have supported software and hardware development, as well as near-term technology improvements for vehicles like Advanced Driver Assistance Systems (ADAS). We have even seen AVs operating in limited commercial settings for public use without a driver since 2020.[121] Despite this documented progress, there are real barriers that must be addressed to scale AVs and fulfill their promise to help save lives, reduce congestion, and provide everyone with greater access to mobility.

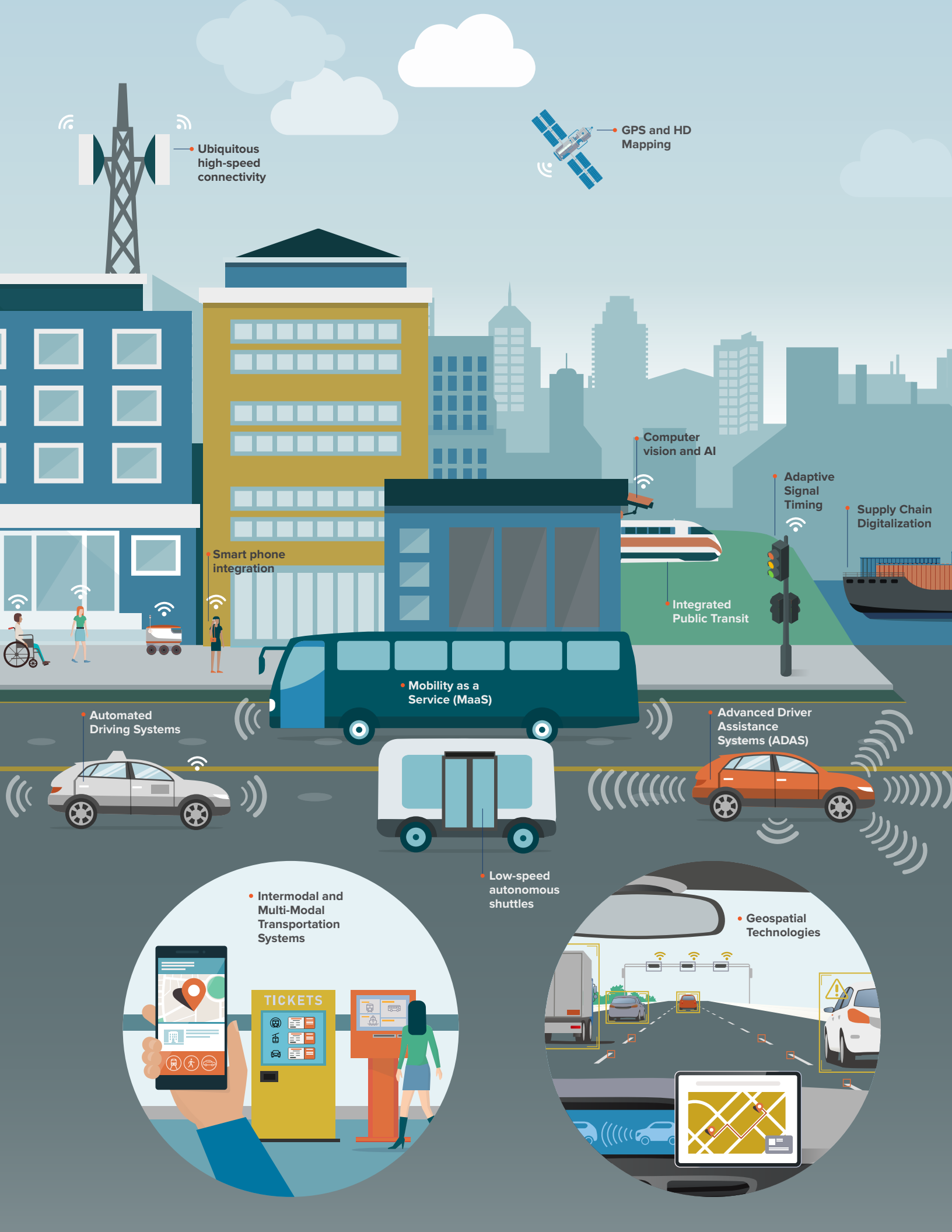
Policy is one such barrier. Since 1968 when the first Federal Safety Standards for cars became effective, motor vehicle regulations have been designed with drivers as an assumed constant. Fast-forward more than 50 years and the United States' regulatory framework has not kept pace with the rapid technological development of autonomous vehicles. Congress

[119]Hod, I. (2023, July 25). Activists hit San Francisco streets, use orange cones to thwart robotaxis. CBS San Francisco.

[120]Hirsch, J. (2022, November 4). Autonomous vehicle reality check after $160 billion spent. Automotive News.

[121]Korosec, K. (2023, May 4). Waymo doubles robotaxi service area in Phoenix in bid to grow driverless trips tenfold. TechCrunch. and Waymo is opening its fully driverless service to the general public in Phoenix. (n.d.). Waypoint. waymo.com/blog/2020/10/waymo-is-opening-its-fully-driverless.html

Figure 6. Landscape of Mobility-Enabling Technologies


Ubiquitous high-speed connectivity
GPS and HD Mapping
Computer vision and AI
Adaptive Signal Timing
Supply Chain Digitalization
Smart phone integration
Integrated Public Transit
Mobility as a Service (MaaS)
Automated Driving Systems
Advanced Driver Assistance Systems (ADAS)
Low-speed autonomous shuttles
Intermodal and Multi-Modal Transportation Systems
TICKETS
Geospatial Technologies

has considered but failed to pass federal legislation for more than half a decade that would clarify how to amend existing laws, including consumer and legal protections. Without federal guidance, authorization for city-level deployments of autonomous vehicle technology for passenger and goods movements is being driven by individual states.[122] This leads to power tussles between state and city policymakers as well as public safety authorities like police and fire departments.[123] More recently, the Biden administration's Unified Regulatory Agenda that was published in June 2023 included a new Notice of Proposed Rulemaking (NPRM) from NTHSA related to AVs, called the *Exemption and Demonstration Framework for Automated Driving Systems*.[124] This proposes a new framework for NTHSA to review and assess certain elements of automated driving systems and AVs, such as exemptions, crash avoidance test procedures, and the incorporation of automated driving systems into commercial vehicles. However, these efforts will not constitute a wholesale federal reform of existing laws and regulations, and additional action is required to support the deployment of this technology.

In comparison, the European Union has already implemented a type of approval system for automated driving systems,[125] and plans to implement a whole vehicle type approval system for autonomous vehicles are under development.[126]

The lack of federal leadership in the U.S. has resulted in testing and deployment of AV technology not being well distributed across all markets, resulting in a limited impact of the technology's broader benefits to the mobility system. However, in a handful of states, mobility innovation is progressing relatively quickly. This is highlighted by states with the most AVs, moving both passengers and freight, such as Arizona, California, Florida, Michigan, and Texas.[127]

Further curtailing the ability to scale AVs and ultimately unlock their potential in the U.S. is an insufficient parallel investment in enabling technologies that make possible the eventual widespread deployment and adoption of AVs. These technologies, several of which are covered below, address aspects such as safety, communication, and infrastructure integration and are fundamental to the feasibility and successful scalability of deploying of AVs, accelerating the transition to a future where AVs play a prominent role in the mobility system.

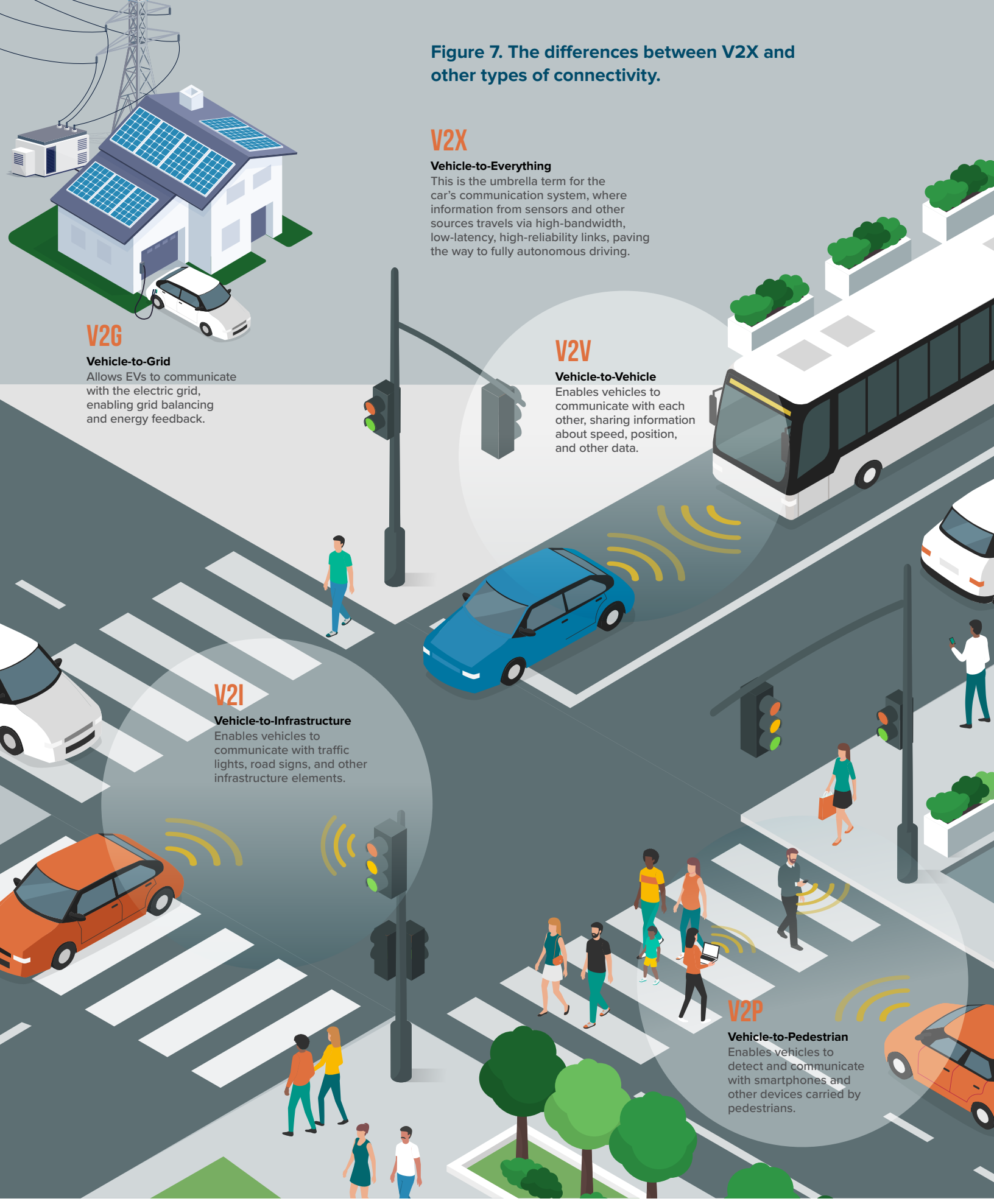
Automotive Connectivity

The era of software-defined vehicles has arrived alongside the build-out of an increasingly robust and distributed communications infrastructure network that can deliver connectivity to the vehicle. According to McKinsey, by 2030 about 95 percent of new vehicles sold globally will be connected, up from around 50 percent in 2021.[128] This connectivity establishes interdependencies between onboard telematics, which connect the car to cloud-enabled services and software in the outside world such as satellite and cellular communications; infotainment services that connect the driver and passengers to Wi-Fi, onboard controls, a head-up display, and in-seat entertainment; and C-V2X communications for safety. The promise of the connected car and its inherent value lie in the fulfillment of a more safe, efficient, and intelligent mobility system overall.

The technical capabilities and capacities of vehicle connectivity are rapidly evolving.[129] As a precursor to full connectivity, software-defined vehicles make it possible to deliver repairs, updates, and improvements via over-the-air firmware updates, via the vehicle's own wireless connection. A connected car has the computing power of 60 to 80 computers on board.[130] A 2021 McKinsey survey found that 37 percent of respondents would switch car brands for improved connectivity, autonomous driving features, digital features, the possibility of shared mobility and electrification.[131] Consumers also

[122]Savrin, D., & Fanelli, M. (2022, September). State—Not federal—Policy guides U.S. autonomous driving | Automotive World. Automotive World.
[123]National Highway Safety Administration. (2023). Exemption and Demonstration Framework for Automated Driving Systems.
[124]Ibid
[125]European Parliament. (n.d.). Regulation (EU) 2022/1426.
[126]Posaner, J. (2022, July). EU plans to approve sales of fully self-driving cars. Politico.
[127]Alliance for Automotive Innovation. (2022). Ready to Launch: Autonomous Vehicles in the U.S. p 14
[128]Bertoncello, Michele, Christopher Martens, Timo Möller, and Tobias Schneiderbauer. (2021). Unlocking Full Value from Data from Connected Cars. McKinsey & Company.
[129]Qualcomm Raises the Bar for Connected Car Technologies with Next Generation Snapdragon Automotive 5G Platform. (2023) Qualcomm.
[130]All there is to know about Software Defined Vehicle. (2023, April 24). Renault Group.
[131]Bertoncello, M., Martens, C., Möller, T., & Schneiderbauer, T. (2021). Unlocking full value from data from connected cars. McKinsey & Company.

Figure 7. The differences between V2X and other types of connectivity.



benchmark vehicle connectivity with the ease of use and features that are available to them on their personal devices like smartphones and tablets.[132]

North America is currently the largest and most developed market for connected vehicle technology. It is predicted that by 2023 there will be 72.5 million connected vehicle units sold.[133] The developments of automotive connectivity have the potential to be leveraged with other mobility technology, such as electric vehicles, vehicle automation, and an "always on" culture. In the United States, transportation agencies have incorporated communications technologies into their operational environments via field systems, operations management centers, and public fleets, and vehicle manufacturers are increasingly including multiple types of communications technologies in their vehicles. While much research has been conducted to date with Wi-Fi, dedicated short range communications (DSRC), cellular, and satellite communications, there are emerging communications technologies such as C-V2X, 5G, and future networks that will also have significant impacts on the mobility system.

While vehicle connectivity provides unique customer experiences and advancements in roadway safety, there have been barriers to arriving at this saturation point.

Despite its time in market, there remains significant confusion among industry stakeholders, policymakers, and the public about the basic vocabulary of automotive connectivity, with terms like C-V2X being used interchangeably with terms like Vehicle to Grid (V2G) or Vehicle to Vehicle (V2V).[134]

Additionally, the full potential of automotive connectivity is currently not being realized in the United States and other markets because connected vehicle data processors and vendors have not yet succeeded in monetizing data, mirroring earlier challenges in monetizing mobile phone data.[135] The situation is unlikely to change unless automakers, component and sensor manufacturers, data infrastructure providers, application vendors and public agencies are motivated to enter into meaningful partnerships – something which will only be driven by a combination of market forces and public policy.

Looking ahead, in order to advance automotive connectivity and fully realize its potential a wide range of stakeholders must be engaged to achieve interoperable connectivity for mobility, including OEMs, suppliers, and infrastructure owner operators across the transportation and communications sectors, and government agencies, which in the U.S. include the Federal Communications Commission (FCC) and the National Highway Traffic Safety Administration (NHTSA).

What's more, public fleets can play an important and early role in demonstrating interoperable connectivity benefits. When the public can interact with automotive connectivity technology and see the benefits of low latency, high bandwidth information exchange platforms that 5G, 6G, and future communications networks enable, they will drive demand, which will accelerate deployments. Delivering a truly smart mobility system that offers extraordinary value by saving lives, reducing congestion, and promoting more sustainable modes of travel.

Vehicle Electrification

EVs have been considered a central pillar of the green transition, and meeting global goals on climate change, and enhancing national security. While prices are dropping and adoption is increasing, there is still concern that active steps are necessary to accelerate both trends. A complicating factor continues to be the underlying technology and particularly the batteries that will power these new vehicles. Additionally, building and maintaining the infrastructure required to support new vehicles remains a logistical barrier. Comparisons between EVs and internal combustion engine (ICE) vehicles are complex, but EVs produce zero tailpipe emissions over their lifetime, making them a critical piece to the future of mobility and solving the larger power puzzle.

Like autonomous vehicles, EVs came to market with the promise of huge potential, but aggressive expectations and

[132]How do consumers perceive in-car connectivity and digital services? McKinsey & Company.

[133]Abdelkader, G., Elgazzar, K., & Khamis, A. (2021). Connected Vehicles: Technology Review, State of the Art, Challenges and Opportunities. Sensors, 21(22), Article 22.

[134]See and Connected and Automated Vehicle Terminology. (2021). Texas Connected and Autonomous Vehicle Terminology Task Force. and What Is Vehicle-to-Grid for Electric Vehicles? (n.d.). EV Connect.

[135]Connected vehicle data market faces setbacks as two of its largest players exit. (2023) S&P Global Market Intelligence.

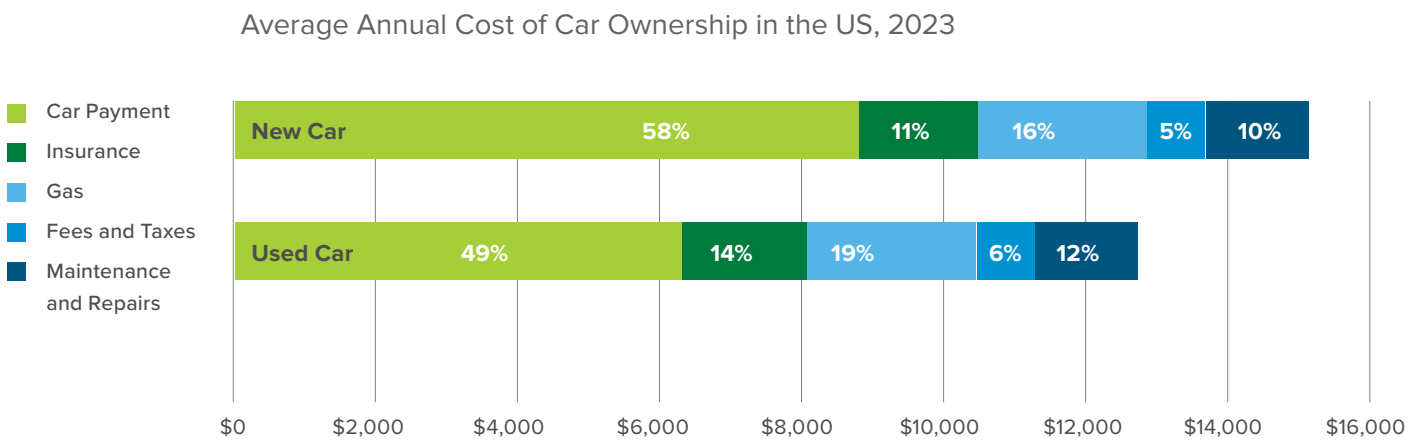
timelines for how they would come to market, be adopted at scale, and make meaningful contributions to achieving climate targets did not yield immediate results. Furthermore, although awareness of EVs is high, 65 percent of Americans have never driven an EV or known anyone who owns one.[136] This results in resistance and skepticism toward considering a purchase.

Setting ambitious goals in the United States, President Biden enacted – though not legally binding – an executive order in 2021 setting a target of having 50 percent of all new vehicles sold in 2030 be electric, a move made in concert with similar pledges made by the biggest U.S. automakers.[137] The effort targeted reducing emissions from cars and trucks, while working to make the United States an industry leader in an growing industry as China has made its own significant national efforts to dominate the electric vehicle market. While this target is achievable it will still require active efforts to hit as according to one analysis, sales of EVs will account for about 30 percent of new car sales in 2030,[138] barring additional efforts.

The shift to electric mobility will fundamentally reduce the economic, national security, and emissions impacts that stem from dependence on oil. There is also extensive value in how vehicle electrification will create new jobs, drive financial savings for consumers and fleet operators and improve air quality by reducing greenhouse gas emissions. But the scaling of vehicle electrification has not been without challenge and blockers, particularly the cost of new vehicles, the minerals and materials that go into batteries, the infrastructure needed to support these vehicles, and the consumer demand to drive purchases.

The growth in popularity of any new technology is influenced by the up-front affordability for consumers. Transportation

Figure 8. How Much Americans Spend on Their Cars Per Year.



Note: Most recent data available used for each source. Assumed 15,000 miles driving per year.
Source: ReMo analysis based on Experian data from Q2 2023 and AAA data from 2023.

[136]Gilman, Sarah. (2023). Understanding the Barriers and Challenges to Greater EV Adoption. Energy Central.
[137]Executive Office of the President. (2021). Strengthening American Leadership in Clean Cars and Trucks. Federal Register.
[138]"EV Sales Forecasts." (2017). EVAdoption. evadoption.com/ev-sales/ev-sales-forecasts/.

in general is becoming less affordable for the average American – transportation costs now represent the second largest household expenditure for Americans.[139] This dynamic is amplified when considering the upfront cost of an EV. The average price of a new EV is around $64,000, compared to roughly $48,000 for a new car of any kind.[140] Meanwhile, the selling price of the average used vehicle is around $30,700.[141] In 2023, over 79 percent of all new vehicles and over 40 percent of all used vehicles in the United States were subject to some kind of financing arrangement,[142] with the average monthly loan payment on a new car being $729[143] and $528 for a used car.[144] When considering car payment costs alongside insurance, gas, fees, and maintenance costs, the average annual cost of car ownership ranges from nearly $12,600 for a used vehicle to over $15,100 for a new vehicle. While on average these costs are substantial, the contributing costs of car ownership can vary widely. Beyond the month-to-month variations in the price of gas that all drivers experience, individuals with lower-cost, older vehicles pay substantially more for maintenance and drivers with lower credit scores face higher car payments.

In addition to consumer cost, the strategic considerations of the minerals and materials required to build the batteries that power EVs has been the subject of extensive political and public discussion. Large quantities of minerals such as copper, cobalt, nickel, lithium, aluminum and rare earth elements are required for electric vehicles and their batteries.[145] The International Energy Agency expects that mineral demand for use in EVs and battery storage is expected to grow by a factor of 30 by 2040.[146] The largest increase is expected in lithium, which could see a seven-fold rise in demand through 2030, mostly driven by EV deployment.[147]

As discussed in SAFE's March 2023 report, *A Global Race to the Top: Using Transparency to Secure Critical Mineral Supply Chains*, China currently dominates nearly all aspects of the critical mineral supply chain – from mining and mineral processing to advanced component production, manufacturing and recycling. The COVID-19 pandemic and the war in Ukraine have shown that highly concentrated supply chains are unpredictable and leave key sectors vulnerable to disruption. The United States and its allies require reliable, resilient access to the materials and components needed for its national defense and economy. At the heart of this is the ability to economically and responsibly obtain the raw or recycled materials needed to support key industries such as the automotive sector. Recycling alone will not be able to satisfy society's rising demand in the near term, and although the existence of raw material to mine is not a critical chokepoint in and of itself, extracting it economically and responsibly is. Furthermore, overcoming the chokepoint of mineral processing cannot be fully addressed until the United States and its allies determine where they will get the material to process and how to get it in a way that does not leave them overly reliant on strategic competitors.

*The United States and its allies require **reliable, resilient access** to the materials and components needed for its national defense and economy.*

[139]Bureau of Transportation Statistics. (2022). "Transportation Economic Trends: Transportation Spending - Average Household."

[140]"Electric Car Prices: The Average Electric Car Cost in 2023." (2023). Find My Electric.

[141]"Used Vehicle Average Selling Price in the United States from 2016 to 2022." 2023. Statista. 2023.

[142]Melinda Zabritski. (2023). Experian State of the Automotive Finance Market Q2 2023, slide 6.

[143]Ibid, slide 22.

[145]IEA. (2021). "Mineral Requirements for Clean Energy Transitions.".

[146]IEA. (2021). "The Role of Critical Minerals in Clean Energy Transitions – Executive Summary."

[147]Note: This upper limit for expected increase in lithium demand is based on IEA's Net-Zero Energy policy, which assumes that global EV sales will increase from 6.6 million in 2021 to 60 million by 2030. Source: IEA, (2023) Energy Technology Perspectives 2023, p 153.

Aerial view of turquoise coloured pools at Silver Peak Lithium Mine, Nevada, California, USA.

On the topic of electrification, the United States has shown substantial recent willingness to coordinate strategic investment in this sector. This is most notable with the recent investments via programs in the Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law (BIL), which have established programs that directly support efforts to build out domestic and allied capacity in the production of EVs and their components, particularly batteries. While this investment is substantial in the context of U.S. and allied nations' financial commitments, and has yielded meaningful shifts in domestic production, it is still insufficient when compared to the sustained investment by global peers like China, who have consistently invested to dominate this space over the past decade.

Mobility-as-a-Service

Mobility-as-a-Service (MaaS) is an evolving concept of how to consider an integrated and seamless approach to providing the transportation that people and businesses demand. Rather than focusing on particular modes or vehicles, MaaS endeavors to focus on users and how to meet their needs most efficiently and effectively. This generally includes the combination of three primary points of innovation: the offering or aggregation of a range of mobility options (e.g., bus, train, bikeshare, ridehailing, etc.); the ability to plan, route, and pay across multiple modes; and the unification of this service in one location without the user having to coordinate across providers or apps.

A particular selling point for MaaS has been the idea of moving away from personal vehicle ownership towards an integrated system of service-based transportation mobility services.[148] This approach aspires to leverage the rapid growth of digital platforms to integrate private and public mobility services to provide users with a single point of access for planning, booking, and paying for their entire journey. By prioritizing convenience, sustainability, and efficiency, MaaS has been a central focus of the transportation community for its potential to enhance urban mobility, reduce congestion, and provide people with flexible and efficient mobility alternatives to private vehicle ownership. However, there continue to be real barriers to scaling MaaS solutions including profitable pricing strategies, challenges of data monetization, "walled gardens" complicating the ability for digitalization systems integration, interoperability in the absence of open data standards, user data privacy sensitivities, and application cybersecurity.

In some markets, particularly in urban areas, the past several decades has seen a rise in on-demand mobility and MaaS. However, as with many other topics in this paper,

[148]Hensher, D. A., Mulley, C., Ho, C., Wong, Y., Smith, G., & Nelson, J. D. (2020). Understanding Mobility as a Service (MaaS): Past, present and future. Elsevier.

the deployment of MaaS has come in fits and starts and not been equally deployed across geographies and populations. Particularly for an offering that centers on integration, markets that are dominated by one mode (e.g., rural areas and individually owned vehicles) have largely seen limited impact of these services, and in markets where there are a multitude of modal options, including innovative new offerings, inconsistent collaboration among and between the public and private sectors have stymied the impact of this concept.

To understand how MaaS might deliver on the promise of its seamless approach to transportation, it is necessary to understand several of the mobility offerings that are regularly included as part of a MaaS platform: ridehailing, micromobility, and car sharing.

Ridehailing

Transportation Network Companies (TNC) like Uber and Lyft have revolutionized on-demand mobility access. Defined as ridehailing, these services connect a rider with a personal driver for hire through a website or mobile app to take them directly to a destination. Note that ridehailing is distinct from ridesharing, which by contrast, is synonymous with carpooling and is the process of a rider sharing a vehicle with other riders that often makes multiple stops to pick up and drop off other riders. Some TNCs do offer both ridehailing and ridesharing services, ridehailing has seen an explosion in popularity while ridesharing services have seen much lower rates of adoption and face an uncertain future in a TNC setting.[149]

Ridehailing has disrupted the traditional taxi industry since its inception in 2010, expanding rapidly and has become a popular choice for millions of people worldwide. However, despite widespread popularity and market dominance, TNCs have struggled to turn a profit. The lack of TNC profitability or revenue growth has been due in part to three main factors, a pricing strategy that often subsidizes rides to attract more customers and gain market share, the significant upfront R&D expense to create and improve the technology and expand service, and a gig economy business model that has fueled legal challenges and lawsuits. While these barriers to scaling exist for most operating in the ridehailing and ridesharing space, Uber recently became the first company to post an operating profit in August of 2023, a major milestone that reflects persistent, strong consumer demand in its core businesses of ridehailing and food delivery.[150]

Today, 36 percent of all Americans have used a TNC service and 26 percent of Americans use these services monthly,[151] demonstrating people's desire for convenient, on-demand mobility. In recent years, additional service offerings and partnerships with transit and other mobility companies by these companies have effectively evolved them into "super apps", providing access to a broader range of on-demand services beyond ridehailing and ridesharing including car, bike or scooter rental, food and grocery delivery and flight booking.[152] As TNCs evolve and expand their services, they remain integral to achieving a sustainable and efficient mobility system. Furthermore, given public transit's limited role in the United States, it is likely that private sector TNCs will continue to drive the growth in on-demand mobility and MaaS platforms.

Micromobility

Leveraging the ubiquity of smartphone access and access to electric motors, bike and scooter offerings have boomed over the past decade with the National Association of City Transportation Officials estimating more than half a billion trips in the U.S. alone since 2010.[153] This includes both dock-less and docked micromobility offerings.

After explosive initial growth in both the number of trips and the number of start-ups entering the dock-less market, recent years have seen challenges with business models and funding; city-level regulations on operators; and travel demand changes during the COVID-19 pandemic leading to a consolidation of dock-less micromobility offerings.[154]

[149]Bellan, R. (2023, March 29). Lyft might drop shared rides, stay focused on basics under new CEO. TechCrunch.

[150]Rana, P. (2023, August 1). Uber's Business Is Finally Making Money After Years of Losses. Wall Street Journal.

[151]Flynn, J. (2023, June). 20+ Riveting Ridesharing Industry Statistics [2023]: Average Ridesharing Revenue, Market Share And More—Zippia.

[152]Georgiadis, P. (2023, May 10). Uber launches flight bookings in UK travel 'super app' push. Financial Times.

[153]National Association of City Transportation Officials (NACTO). (2022, December 1). Americans Have Taken Half a Billion Bikeshare and E-Scooter Trips Since 2010.

[154]Heineke, K., Kloss, B., & Scurtu, D. (2020). The future of micromobility: Ridership and revenue after a crisis. McKinsey & Company.

Visualization of Cruise Origin concept driverless shuttle on city streets

Despite the impact of the pandemic, recent data suggests that this sector is back on a trajectory of significant growth, with docked bikeshare has been particularly resilient as dockless scooters have been slower to recover ridership.[155]

Car sharing

With the average car parked more than 95 percent of the time,[156] the idea of accessing a shared use car when you need it has been a logical alternative to personal vehicle ownership. While there was an initial rush of providers standing up operations based on this model – both fleet operation and peer-to-peer rental – including new initiatives by legacy automakers, this model faced similar challenges to micromobility and TNCs. Issues monetizing services, working effectively with cities, and displacing the entrenched bias of many users toward personal vehicle usage, saw consolidation of the industry and a reduction in the regional scope and number of providers.[157]

While each of the components above present their own challenges to a successful MaaS framework, the crosscutting stumbling block has been how to reconcile the individual priorities of private companies with the need for interoperability and integration. Despite these blockers, the MaaS market is projected to exceed $230 billion worldwide by 2025,[158] and while early entrants have struggled to show substantiated revenue growth over time, they have successfully helped shape the discussion and brought integrated journey-planning and alternative, viable options to private vehicle ownership, to the future of mobility discussion.

Novel Vehicle Form Factors

Vehicle design is undergoing a transformation driven by technological innovations and evolving urban dynamics. From self-driving cars that redefine the traditional driving experience to autonomous trucks that could reshape the logistics industry, these innovations hold the potential to change the way we move goods and people. Furthermore, the rise of smaller electric vehicles (EVs) has the potential to reshape urban mobility, offering efficient and eco-friendly alternatives to cars for short-distance travel. Lastly, micromobility transportation modes, including electric scooters and bicycles, are playing a pivotal role in addressing the last-mile connectivity challenge and reducing the environmental footprint of urban commuting. The current opportunity for mobility innovation includes vehicle form factor because advances in technology mean we can reconstruct the design of vehicles and other transportation modes to better match a specific use case.

New autonomous vehicle (AV) form factors represent a particularly transformative wave in the transportation industry, with the potential to usher in innovative designs that reimagine the way we move people and goods. Because of their focus on a specific use case or operational domain, these vehicles can depart from traditional car configurations, offering unique features that prioritize efficiency, sustainability, and adaptability to the evolving urban landscape. New form factor vehicles can also provide greater mobility for people, such as people with disabilities or the elderly, who currently struggle to access or use traditional transportation.

One key characteristic of these new AV form factors is their emphasis on spatial efficiency. Many of them are purpose-built, optimizing interior layouts to maximize usable space. This shift often means vehicles without traditional features, such as steering wheels and driver's seats, making way for more comfortable seating arrangements, modular interiors, or cargo compartments. This spatial efficiency not only enhances user experience but also reduces the overall footprint of these vehicles, aiding in congestion reduction and resource optimization

[155]Bikeshare Roars Back From the Pandemic. (2022, December 1). Bloomberg.

[156]'Cars are parked 95% of the time'. Let's check! (2013, February 22). Reinventing Parking.

[157]GM Shuts Down Maven Car-Sharing Service after Four-Year Experiment. (2020, April 24). Autoweek.

[158]Global MaaS market size 2017-2025. (n.d.). Statista.

in densely populated urban areas. This spatial efficiency also offers the potential to accommodate mobility needs of people not currently adequately served by transportation.

The emergence of new AV form factors signifies a broader shift towards innovative designs that prioritize functionality, sustainability, and shared mobility. These vehicles are poised to play a pivotal role in shaping the future of transportation, improving urban livability, and contributing to more efficient, sustainable, and accessible mobility solutions as our cities continue to evolve and grow.

Policies that incentivize a greater variety of right-sized and novel vehicle form factors are an effective way to solve both the supply chain, sustainability and affordability challenges associated with the current fleet of electric vehicles, while still maintaining people's freedom of choice in the way they get around. Recent research has found that with no or little change to the current levels of vehicle ownership in the United States, reductions in the size of EV batteries (to an average of 35kWh) could cut lithium demand by between 29 to 42 percent by 2050.[159] Across the Atlantic, recent European research has found that smaller EVs in combination with modest changes in mobility behavior would require a third less lithium, half as much nickel, 44 percent less cobalt and a third less manganese by 2050.[160] By lowering critical mineral demand for EV manufacturing, pricing pressure can also decrease, enabling the acceleration of developing new, more affordable vehicle models. A reduction of supply side constraints for all manufacturers would also likely accelerate increasing competition between auto manufacturers to reduce prices, which ultimately benefits consumers.[161]

U.S. automotive industry leaders have started to recognize these risks and opportunities but have not spoken directly to the scope of the entire issue. For example, Ford's CEO Jim Farley has called the supply chain for critical battery minerals the key constraint to accelerating EV production.[162] General Motors CEO Mary Barra has said "You still have to cover the market for what people can afford … to get to a point where there's many EVs being sold in the U.S., recognizing competition as well, you have to meet the customer where they're at from an affordability perspective."[163] Stellantis CEO Carlos Taveres has said: "The most significant problem of electrification is the affordability for the middle classes …. That's what we are now fighting against – how fast can we reduce the costs to bring the EV to the level of affordability that people can pay for without subsidies?"[164]

While it is certainly true that even greater efficiencies and mineral savings could be achieved with reduced car usage and ownership and large-scale mode shifts to transit, walking and cycling[165] – significant behavioral shifts in consumers would have to occur. Climate change, energy and economic crises are amplifying the effects of increasing costs of living and growing economic inequality across the developed world. The reality is that we can only solve the challenges we face and enhance the prosperity and well-being of society by providing affordable transportation solutions that are compelling to people. People need to feel like their lives are getting better and easier – not worse or more difficult.

If policymakers and auto manufacturers in the United States and allied countries do not address this hard truth about electric vehicle mineral dependencies and consumer affection for automobiles, then China directly stands to benefit. According to one automotive sector expert, "we [Europe and the U.S.] don't know how to make small cars with affordable batteries …. China knows it."[166]

Collectively, novel vehicle form factors can usher in an era of diversified and sustainable mobility options. As cities continue to evolve, these advancements have the potential to redefine the way we move and shape our urban and rural environments

[159]Riofrancos, T., Kendall, A., Dayemo, K., Haugen, M., McDonald, K., Hassan, B., Slattery, M., & Xan, L. (2023). Achieving Zero Emissions with More Mobility and Less Mining. Climate and Community Project (CCP). P 7, p 35-36 and Table 3 on p 39.

[160]Compared with a business-as-usual scenario. Racu, Alina, Luca Poggi, Julia Poliscanova, Thomas Earl, and Cecilia Mattea. 2023. "Battery Metals Demand from Electrifying Passenger Transport." Transport & Environment.

[161]Mullaney, Tim. 2023. "The $25,000 Electric Vehicle Is Coming, with Big Implications for the Auto Market and Car Buyers." CNBC, April 16, 2023.

[162]Johnson, Peter. 2023. "Ford CEO Says Battery Supply Is EV Production Constraint." Electrek, March 2023.

[163]Financial Times. 2023. "Will a Price War Accelerate the Switch to Electric Cars?" May 2023.

[164]Swallow, Tom. 2023. "Stellantis Says Affordability Is Crucial for Electrification," February 23, 2023.

[165]For example, the UC Davis research found that lithium demand could be reduced by up to 66 percent in a scenarios where U.S. car ownership and use is reduced and EV battery size is limited. See p 7 UC Davis report.

[166]Irwin, John. 2023. "Personal Mobility at Risk without More EV Innovation, Forvia CEO Says." Automotive News Europe. January 2023.

for the better. As one example, micromobility vehicles like e-scooters and e-bikes offer consumers with affordable, right-sized vehicles that are a convenient middle ground between walking and driving for short distances for which it would be inconvenient to walk and overkill to drive.[167] These smaller vehicles are a small segment of the overall transportation sector, but they continue to grow in popularity in the United States. The Fluctuo Annual Review[168] shows that in 2021, there were 128 million shared bike and scooter trips, of which 58 million were docked bikeshare trips, 8 million were free floating bike trips and 62 million were e-scooter trips.

Transportation Data and Analytics

A product of vehicle automation, connectivity, and electrification has been an explosion in the data coming from vehicles, infrastructure, and from other sources that can help to understand and inform how users move through the transportation network. Projections indicate that global traffic data, just one application of connected vehicle data, is set to experience an exponential surge, reaching up to 10 exabytes per month by 2025.[169] This growth is underpinned by the surge in digital data across all sectors of business and society, leading to the quote widely attributed to British mathematician Clive Humby that "data is the new oil." But much like oil, in its unrefined state data is largely unusable. Like oil, data must be effectively refined and processed to be useful for different applications.[170]

While rapidly increasing data generated from the new mobility landscape holds immense potential, harnessing this potential will require standardization, interoperability, and strategies to effectively apply data-driven analysis to transportation challenges. The ability to maximize the benefit of increased data generation will depend on an interconnected infrastructure framework that can accommodate the demands of a

Minimobility

Another example that is one scale up in size from micromobility is minimobility. Minimobility has no fixed definition but includes three- or four-wheeled electric vehicles (EVs) that fit one to two people. These vehicles have an average weight of between 220 and 1100 pounds. Depending on the vehicle type and local regulations, their maximum speed varies from 15 to 55 miles per hour.[171] Examples include the Michigan-based Nimbus pod EV, which is classed as an autocycle and is regulated at the state level.

Minimobility vehicles have a lower mass than ordinary automobiles and need approximately 1/3 of the material mass for production.[172] Based on a review of safety literature, including NHTSA's own assessment of lightweighting and other mass reduction technologies, there are limited safety risks associated with smaller vehicles.[173] More familiar types of minimobility vehicles – golf carts – are already a popular mobility mode in some U.S. suburbs.[174]

The total addressable market for right-sized vehicles and new form factors could reach $100 billion annually across the globe by 2030, while bringing the added benefits of decreased congestion, reduced space requirements for parking, efficiencies in the manufacturing process due to less material mass required for production, and lower emissions.[175] For short trips in a U.S. urban environment, a minimobility service, for example, would let people access a right-sized electric vehicle on demand, that can operate on existing roads with protection from weather, storage capacity, privacy, and comfort. Not only would this kind of service be affordable and accessible, but it would meet the actual day-to-day transportation needs of city-dwelling Americans.

[167]Kopplin, C. S., Brand, B. M., & Reichenberger, Y. (2021). Consumer acceptance of shared e-scooters for urban and short-distance mobility. Transportation research part D: transport and environment, 91, 102680.

[168]"European Shared Mobility Index Q2 2023." 2023. Fluctuo Mobility Enablement.

[169]Dickert, C. (2023, March 15) "Network Overload? Adding Up the Data Produced By Connected Cars," Visual Capitalist.

[170]Talagala, N. (2022). Data as The New Oil Is Not Enough: Four Principles For Avoiding Data Fires. Forbes.

[171]Minimobility: The next big thing in urban mobility? (2022) McKinsey & Company.

[172]Riggs, W., Shukla, S. (2021). Exploring the benefits of minimobility in the urban context: The case of central Stockholm. Journal of Transport and Land Use, 14(1), 1019–1037.

[173]Securing America's Future Energy. (2018, October 26). Fuel Efficiency Standards Should be Modernized to Expand the Use of Advanced Fuels, Promote Driverless Technologies, and Strengthen U.S. Energy Security. Washington, DC.

[174]Zipper, David. 2023. "The Electric Vehicle That Suburbia Needs Could Be a Golf Cart." August 2023.

[175]Minimobility: The next big thing in urban mobility? (2022) McKinsey & Company.

The interconnectedness of vehicles, sensors, and communication systems could allow for ***unprecedented levels of coordination and efficiency in the transportation of goods.***

rapidly evolving mobility ecosystem along with systems and practitioners who can put this data to work.

With the proliferation of sensors like radars, cameras, and lidar on automated vehicles, data generated has the potential to provide users, businesses, policymakers, and public authorities with real-time insights into road conditions, traffic patterns, vehicle behavior, and much more. This wealth of connected vehicle data, with the right direction, has the potential to enable enhanced vehicle-to-vehicle communication, improve safety and congestion management, and empower urban planners and policymakers to make informed decisions regarding infrastructure development and traffic management strategies. Leveraging this data effectively has the potential to create more efficient, safer, and environmentally sustainable transportation networks that cater to the evolving needs of modern societies.

Many consumers are already familiar with ways that data and analysis can improve their individual travel experience. Access to real-time traffic conditions delivered via in-vehicle or on mobile device navigation along with accurate predicted travel times and guidance for what route to choose is now considered commonplace. Live information about bus or train arrival time makes taking transit more reliable. Smartphone access to the availability of bikes at nearby docked bikeshare stations makes opting to bike to work a more convenient option.

Less visible but more transformational are the ways that data and analytics can improve performance and outcomes across the transportation system as a whole. Road authorities can be immediately notified about and respond to a crash or incident when aggregated shows speeds begin to drop or a queue begins to form. Dockless micromobility fleets can be monitored to prevent vehicles blocking sidewalks or failing to deliver promised levels of service. Bikeshare stations availability can be leveraged in real-time to rebalance vehicle distribution during the day and analyzed historically to proactively ensure that bikes are available when and where they're likely to be in highest demand. Data on vehicle speeds, pedestrian activity, and historical crashes can be analyzed to make faster progress toward Vision Zero goals.[176] And broadly data and analytics can be used to better target limited transportation funds to the projects that will have the biggest impact, provide key metrics to assess the impact after completion, and allow for faster refinement to drive better outcomes.

While there is a tremendous amount of data being generated by and about the transportation mobility sector, there have been limiting factors to seeing the impact of this trend on a system-wide level. This includes the lack of a coordinated approach, such as standardization, to how to use and structure data; inadequate public funding to source and use available data; challenges of how to monetize vehicle data and analytics; and an uncertain and shifting landscape around how to consider privacy and security of data that can be used to make better decisions. To effectively address these blockers, coordinated leadership between the public and private sectors is required that starts with agreeing on the fundamental impact desired (e.g., fewer crashes, increased system efficiency, higher transit ridership, or lower emissions) and then identifies the data and analytics needed to drive this outcome.

The convergence of electrification technologies in tandem with transportation data and advanced infrastructure will impact goods movement across the broader supply chain. The interconnectedness of vehicles, sensors, and communication systems could allow for unprecedented levels of coordination and efficiency in the transportation of goods. Autonomous and connected vehicles, guided by real-time data from sensors and communication networks, can optimize delivery routes, anticipate traffic congestion, and dynamically adjust schedules, ultimately reducing delivery times and enhancing overall supply chain reliability. There is still much

[176]https://visionzeronetwork.org/about/what-is-vision-zero/

work to be done in understanding the efficiency and energy saving potential of this convergence, and what it means for policy development.

Moreover, the wealth of data generated by these technologies can be harnessed to refine supply chain operations. Precise information about vehicle location, road conditions, and traffic patterns can lead to more accurate demand forecasting, streamlined inventory management, and improved route planning. This data-driven approach has the potential to minimize waste, reduce costs, and enhance resource allocation across the supply chain.

The development of an ecosystem capable of manufacturing and supporting autonomous, connected, electric, and shared mobility is pivotal in reshaping how we navigate and interact with the world. It is not merely about constructing physical elements but enabling technologies and physical components to work together to facilitate safer, more efficient, and more sustainable transportation solutions.

Nega-watts and Nega-miles

Energy physicist Amory Lovins first introduced the idea of a nega-watt in the 1970s. The concept was simple – the cheapest and greenest unit of electricity was the unit not used. Instead of investing in a new power plant to meet increased electric demand, invest in using less electricity, reducing societal use, environmental impacts, and consumers' bills.[177]

Today's biggest energy challenge world-wide remains the over reliance and use of fossil fuels to power the transportation sector, especially motor vehicles. The electrification

The Nuro R2 autonomous on-road delivery vehicle

[177]To Solve Transportation GHG Emissions, Create a New Organization. (2021, October 6). Sustainable Transportation Vermont.

Credit: https://www.nuro.ai/media-kit#media-kit-photography

transition will not solve this challenge alone. Changing transportation habits will. The parallel measure to the nega-watt in transportation is the nega-mile – a mile not traveled in a personal motor (or electric) vehicle due to trip reduction or trip optimization. Further, the convergence of information and communication technologies with the mobility system has affected the trips people take as well as the trips people do not take.

Energy utilities and policymakers have increasingly invested in nega-watts through policies and programs, such as building efficiency upgrades, that reduce demand on the grid, avoid costly capital upgrades to the energy system, and lower energy prices for customers.[178] The intersection of technology and transportation offers opportunities to advance the nega-miles in transportation concept and provide real alternatives to traveling in an automobile through transit and MaaS expansion, pedestrian infrastructure and urban planning efforts that support people moving towards less auto-dependent life styles.

Another opportunity for advancing the nega-miles concept, in addition to reducing the vehicle trips that people take, is further optimizing the trips they do choose to take. Information and communications technology opens new combined passenger and last-mile goods trips that increase the operational efficiency of vehicles and create diverse potential value pools for businesses. In a reimagined mobility future, the vehicle that delivers your groceries could then bring your neighbor to the train station along the same route back to the service operator's distribution center. This type of business model may also be appealing in geographic areas with large elderly populations – keeping people connected, mobile, and healthy when they are no longer able to safely drive themselves.

Assessing the opportunities for out-of-the-box thinking for policies, programs, and investments to harness the nega-miles concept can also reduce the demand on the materials and critical minerals needed to significantly reduce the transportation sectors dependence on oil through electrification and new mobility technologies. Strategic systems-level thinking on how best to leverage technology and the growing trend of trip avoidance could yield measurable environmental benefits as well as give people back personal time spent commuting or running errands.

The Size of the Prize: The Benefits of a Transformed Mobility Landscape

When considering the "why?" for the urgency to deliver on the potential of a 21st century transportation mobility system there are three categories of benefits that should be considered: the greatest hits, the second-order benefits, and strategic macro impacts.

[178]Stahl, J. (2012, November 28). Welcome the Negawatt Revolution. Slate.

The Greatest Hits

For more than two decades those working on the technology and policies that would define a 21st century transportation mobility system has presented a case for how these solutions will address inefficiencies, inadequacies, and failures in our current system.

New transportation and communications technologies would reduce over 2.3 million injuries per year, save $800 billion dollars annually due to reduced congestion, and abate nearly 87 million tons of CO_2 in the transportation sector alone.[179]

When technology is leveraged to improve the efficiency of how people access goods and services, these potential gains expand. By 2050, the cumulative consumer and social value of AVs is projected to be between $3.2 and $6.3 trillion.[180] This value is likely to manifest in ways such as increased access to goods, services, education and employment opportunities, enhanced social connections with friends and family, new mobility choices and goods delivery options, and more efficient and affordable goods transport for businesses.

As connected and autonomous driving technologies reach a state of maturity, they will emerge not only as a catalyst for enhanced road safety but also as a cornerstone for lucrative businesses that enhance people's access to goods, services, and the world around them. These ventures could thrive by offering meticulously curated fleets of right-sized vehicles, finely attuned to diverse trip demands, and seamlessly deployed according to the unique preferences of their customers. All of this unfolds within a broader landscape of ever-evolving information and communication technologies that offer every user the unfettered access to a multitude of activities, from work and shopping to healthcare, education, socializing, and entertainment. This vision is underpinned by the electrification of transportation, which is the only realistic method of reducing U.S. and allies' dependence on oil and reducing air pollution and emissions associated with transportation. In this empowering realm of technological advancement, the constraints of travel fade away, replaced by newfound flexibility, abundant choices, and a reduction in costs for all. Additionally, there are compelling opportunities to address issues that the current transportation system has either driven or failed to fix, which are frequently cited as reasons to support scaling of these solutions. These include the alarming expansion of food deserts,[181] the inequity in access to transportation for those with mobility limiting disabilities,[182] the increase in fatalities for vulnerable road users,[183] social justice issues with air and noise pollution disproportionately impacting lower income populations and communities of color,[184] and expanding access to jobs, healthcare, and other key services for underserved communities where access to transportation is a key limiting factor.[185]

When technology is leveraged to improve the efficiency of how people access goods and services, ***these potential gains expand.***

While these problems have been regularly cited as an immediate reason for action to test, deploy and scale new solutions, their aspirational nature and scale required to deliver step change results have meant that, despite significant progress

[179]SAFE. (2018). America's Workforce and the Self-Driving Future. p 21.

[180]Ibid

[181]Sisk, A., Rappazzo, K., Luben, T., & Fefferman, N. (2023). Connecting people to food: A network approach to alleviating food deserts. Journal of Transport & Health, 31, 101627.

[182]Henly, M., & Brucker, D. L. (2019). Transportation patterns demonstrate inequalities in community participation for working-age Americans with disabilities. Transportation Research Part A: Policy and Practice, 130, 93–106.

[183]"Vulnerable road users, such as pedestrians, cyclists, and people who use wheelchairs, accounted for approximately 20% of the 42,915 people who were killed in motor vehicle crashes in 2021, according to the National Highway Safety Administration, an increase of 13% over 2020." See U.S. Department of Transportation Announces New Guidance to Improve Safety for Vulnerable Road Users under President's Bipartisan Infrastructure Law. (2022, October 21). US Department of Transportation.

[184]Whitmore, A. (2023). Environmental and Equity Implications of Electric, Shared Autonomous Vehicles (SAVs) in Urban Transportation: A Case Study of San Francisco. SAFE.

[185]Fostering Economic Opportunity through Autonomous Vehicle Technology. (2020). SAFE.

being made on development and testing, the public perception is that these solutions have fallen short or failed to deliver.

While it is important to not lose sight of the big, bold reasons to invest in these solutions, it is essential that policymakers and the public also be presented with the immediate impact that they can expect to see from investments in innovative new technologies and policies.

The Spillover Effects

While the potential for new mobility technologies to address some of the most pressing transportation, energy, and environmental challenges, there are compelling reasons to invest in their development, testing and deployment beyond these direct reasons. This includes the ability for research and investment associated with automation, connectivity, electrification, and data analytics to unlock advancements in other applications.

For example, investments to date in AV technology have contributed not only to the advancement of self-driving vehicles but have also spurred innovations in related industries. Research and development into AVs have catalyzed progress in electric and alternative fuel vehicles, data analytics, and connected vehicle technology. As a result, the benefits of AV investments extend beyond autonomous driving, fostering an ecosystem of cutting-edge technologies that will shape the future beyond transportation. Furthermore, the countries that lead in the development of these transportation technologies and successfully integrate them into the transportation system will enjoy the economic benefits of creating and securing a leading position in the industries that will define the decades to come.

This has parallels with the spillover benefits of policy prioritization and investments into space technologies. The space race and space programs of the 20th century led to numerous technological advancements that, while originally developed for space exploration, found applications in everyday life on Earth, resulting in a myriad of spinoff benefits. One of the most recognized is the development of satellite technology, which has revolutionized global communication and meteorology.[186] Teflon-coated fiberglass, initially used as a material for astronaut suits,[187] became popular as roofing material for stadiums and malls. Digital signal processing, which was crucial for large-scale data interpretation from space missions,[188] is now employed in medical imaging like MRI scans. In the medical field, telemedicine saw a leap in development due to NASA's efforts to monitor astronauts' health remotely.[189] These are just a few of the countless innovations that have their roots in the ambitious objectives of the space programs, underscoring the broader societal returns from investments in cutting-edge, experimental technologies.

Geopolitics and National Security

Beyond the economic, consumer, and societal reasons to invest in these new technologies, the geopolitical implications surrounding domestic capacity and secure allied supply chains are necessary to consider preventing overreliance or market dominance by any one country. We have seen the downside of ceding leadership on key technologies in the case of advanced batteries and the critical minerals and materials required to produce them. Despite significant national investments made in recent years in the United States. through landmark legislation like the Bipartisan Infrastructure Law, Inflation Reduction Act, and CHIPS and Science Act, additional investment, coordination, and strategy is needed to close the gap with international peers like China.

Related to these geopolitical considerations, are the national security implications of where these key technologies are developed. These are significant, and warrant a substantial amount of analysis, which the Coalition for Reimagined Mobility expects to cover in follow on work.

[186]Whalen, David J. 2010. "Communications Satellites Short History: Making the Global Village Possible." NASA (blog).

[187]National Air and Space Museum. n.d. "Armstrong Spacesuit."

[188]Smith, Steven W. 2011. The Roots of DSP. California Technical Publishing.

[189]Patrinos, Thalia. 2020. "NASA and Telemedicine." NASA.

The Changing Landscape for Global Competitiveness

As described above, the world is experiencing the most important shift in the movement of people and goods since the invention of the automobile. Driven by the convergence of Detroit and Silicon Valley, many have asserted that American ingenuity will lead a global innovation revolution of historic proportions – one that meaningfully accelerates adoption of electric vehicles, the development of autonomous and vehicle connectivity technologies, as well as the associated component manufacturing and infrastructure in the built environment to support deployment at scale. Recent history has demonstrated that this will not happen organically.

U.S. leadership in these technologies will generate important benefits for the country, including reduced emissions, increased energy and national security, manufacturing competitiveness, employment growth, and the assurance that the nation will retain its position atop the global economic order.

Yet, for as much promise as America's advancements in advanced mobility technologies hold for the country's outlook, the United States faces an uncertain future replete with profound risks. China, with its increasingly assertive stance on the international stage, is challenging the United States for global leadership over the next generation of advanced mobility technologies – and by many indications has already claimed the lead. After decades of economic preeminence, the United States and its allies must – in some instances – play catch up to contend in a world in which a rising China has moved up the manufacturing value chain and built globally competitive companies and technologies that will have an enduring impact on who captures the economic value of the movement of people and goods.

The United States and its allies cannot afford to lose the manufacturing and development capacity – people, equipment, research and development, and management and organizational skills – of a vibrant and healthy advanced mobility technology industry. If such capacity is lost, or severely degraded, it would not only threaten the U.S. and industrialized economies and millions of jobs, but in the particular

case of the United States, it could also undermine the nation's capacity to innovate, with implications for the military and defense industry and society's ability to tackle other generational challenges such as climate change.

The Strategic Economic Importance of Automotive Manufacturing

The automotive industry has, for more than a century, been a powerful driver of the American economy, accounting for up to five percent of U.S. gross domestic product and injecting $1 trillion into the economy each year.[190] The auto sector is a major source of employment, both directly within the auto manufacturing companies and indirectly in ancillary industries such as parts suppliers, dealerships, and service providers. Its importance to the economy also reflects the depth of its supply chain, given that 75 percent of the value of its output pays for intermediate materials.[191] The automotive industry is also a hub of innovation, and the results of its research and development often have spillover effects into other industries, promoting broad-based technological advancement, including for defense purposes. Furthermore, the U.S. automotive market attracts significant investments and fosters international trade.

As the industry shifts toward electric and autonomous vehicles, ***these new technologies hold the potential to level the playing field and create an opening for new entrants.***

The automotive sector is similarly crucial to many of the major economies around the world and is often seen as a necessary foundation for an advanced industrial base. The European automotive sector, for example, is Europe's top investor in research & development and it delivers an annual trade surplus of $85 billion and generates $397 billion in taxation for governments in major EU markets.[192] In the United Kingdom, automotive-related manufacturing contributes $82 billion turnover and $17 billion value added to the economy, and typically invests around $3.7 billion each year in R&D.[193] In the Asia-Pacific region, Japan's automotive sector is one of the main pillars of the country's manufacturing-focused economy, employing 5.5 million people (more than 8 percent of the workforce) and comprising nearly 18 percent of all exports.[194] South Korea's automotive sector was responsible for roughly 12 percent of Korea's manufacturing employment, 13 percent of production, and 12 percent of total exports.[195]

As the industry shifts toward electric and autonomous vehicles, these new technologies hold the potential to level the playing field and create an opening for new entrants. China is one of those new entrants and it has become a global automotive powerhouse, seeking to build a global reputation for its companies and further bolster its growing industrial base at home. Chinese manufacturers, backed by substantial state support and massive domestic demand – in large part due to regulation – are rapidly advancing in both technology and scale. With China's aggressive push into connected, electric and autonomous vehicles, it is a formidable challenger with the potential to alter the competitive landscape currently dominated by well-known global automakers.

As will be discussed in more detail below, Beijing has unambiguously identified its national priorities in the transportation sector, which, if executed successfully, will present significant

[190] Alliance for Automotive Innovation. (2022). The Driving Force.

[191] Hong, S., Shell, H., & Sun, Q. (2019). How Important Are Production Networks to the U.S. Economy? Federal Reserve Bank of St. Louis.

[192] September 2023 conversion to U.S. dollars of an annual trade surplus of €79.5 billion and generates €375 billion in taxation. See The state of the EU auto industry. (2022, September 30). ACEA - European Automobile Manufacturers' Association.

[193] September 2023 conversion to U.S. dollars of £67 billion turnover, £14 billion value added to the economy and £3 billion each year in R&D. See Society of Motor Manufacturers and Traders. (2022). UK Automotive.

[194] Japan Automobile Manufacturers Association, Inc. (2022). The Motor Industry of Japan.

[195] InvestKorea. (2022). Korea's Automobile Industry and the Development of EVs and Self-Driving Vehicles.

challenges to the United States. Confronting those challenges will not be easy. It will first require an honest assessment by policymakers of any potential risks to its economic and national security. In the best case, this risk amounts to a significant loss of jobs as the United States cedes some advanced mobility technology and automobile manufacturing to China. At worst, it amounts to handing a strategic competitor sensitive and economically important data and a severe degradation of the U.S.-based innovation ecosystem – a system which catalyzes future economic growth and enables the United States to stay ahead in the technological, industrial, and military competition.

China's Success in New Transportation Technologies

China's strategy toward shaping the future of advanced mobility technologies has two primary objectives. First, establish a globally competitive Chinese electric vehicle industry; and second, pour investments into the longer-term development of autonomous and connected vehicle technologies that leverage a 5G network. Through the implementation of ambitious, state-led industrial policies, China has been able to operationalize this strategy effectively.

A Globally Competitive EV Industry

The primary factor behind China's growing strength in the automotive sector is its national strategic commitment to creating an EV market and supply chain.[196] This commitment began with the inclusion in 2001 of EV technology as a priority science research project in China's national economic blueprint, the Five-Year Plan. In 2006, China began implementing policies to incentivize private companies to produce EVs.[197] China's Ministry of Science and Technology (MOST) and the National Development and Reform Commission (NDRC) launched preliminary programs to fund electric vehicle research and development. The first of such programs,

"Made in China 2025" is a state-led initiative to make China dominant in global high-tech industries.

Project 863, was a precursor to Made in China 2025 – an industrial policy plan designed to guide and expedite China's evolution into a high-technology manufacturing superpower and global innovation hub. Project 863 provided funding for more than a dozen high-tech industries, including $174 million for EVs, which represented the first substantial allocation of funds toward EV development.[198] In 2008, MOST and NDRC announced that they would put at least 1,000 hybrid, fuel-cell, and all-electric vehicles on the road in 10 different cities.[199] Then from 2009 to 2022, the Chinese government poured $29 billion into subsidies and tax breaks for EVs, a bold policy commitment that has delivered measurable results.[200]

Early investments in EV technology led China to become the global frontrunner in electric vehicle sales, accounting for roughly 60 percent of global sales in 2022.[201] Today, more than half of the world's electric cars on roadways are in China and the country has already exceeded its 2025 target for sales. There are more than 300 models of EVs available to Chinese consumers, which far exceeds availability in any other country. China's domestic EV market is also supported by robust infrastructure development, for example, at the end of 2022 China had 760,000 fast charging stations in operation.[202] China is also at the forefront of battery swapping

[196]Cheng, E. (2020, May 3). Electric cars take the spotlight in China's post-coronavirus stimulus plans. CNBC.

[197]Ou, S., Lin, Z., Wu, Z., Zheng, J., Lyu, R., Przesmitzki, S. V., & He, X. (2017). A Study of China's Explosive Growth in the Plug-in Electric Vehicle Market.

[198]U.S. Chamber of Commerce. (2017). Made in China 2023: Global Ambitions built on Local Protections. and IEA, International Energy Association. (2012). Hybrid and Electric Vehicles: The Electric Drive Captures the Imagination. p 192.

[199]See, e.g., William Pentland, "Why China May Save The Electric Car," Forbes, October 27, 2008.

[200]Yang, Z. (2023, February 21). How did China come to dominate the world of electric cars? MIT Technology Review.

[201]Executive summary – Global EV Outlook 2023 – Analysis. (n.d.). IEA.

[202]Trends in charging infrastructure – Global EV Outlook 2023 – Analysis. (n.d.). IEA.

technology for trucks, and almost all major Chinese heavy-duty truck manufacturers have swappable battery models, perhaps enabling China to electrify this market segment more quickly than its peers. In 2022 alone, more than 12,000 of such trucks were sold in China.[203]

While it may be surprising to some outside of China, Chinese automakers are already exceeding some U.S. and allied automotive manufacturers with the build quality and affordability of their EV models. J.D. Power, which produces globally respected market surveys on vehicle quality, measures vehicle quality by the number of problems per hundred vehicles produced. In 2023 the average Chinese EV had 173 problems per hundred vehicles.[204] In contrast, the average rating of some high-profile U.S. EV models was 298 problems per hundred vehicles.[205] In terms of affordability, the average price of an electric vehicle in China is significantly lower than in the rest of the world, around $35,000 compared with $60,000 in Europe and $70,000 in the United States – though the price differential can also be explained by varying labor costs, consumer preference for battery size and performance, among other factors.[206]

Average Price of an Electric Vehicle

$35,000
in China

$60,000
in Europe

$70,000
in the United States

Source: See for example EV price war: China winning, Europe and US losing. (2022, October 6). Fleet Europe; and Electric Car Prices: The Average Electric Car Cost in 2023. Find My Electric.

After finding success in the domestic market,[207] Chinese auto manufacturers are executing a plan to proliferate across international markets, which is a key step toward becoming globally competitive in the automotive sector. Over a four-year period from 2018 to 2022, the value of passenger vehicle exports from China increased from approximately $9 billion in 2018 to nearly $45 billion by 2022, nearly reaching the $58 billion of U.S. passenger vehicle exports in 2022. While this figure includes the ICE market, and China is a leader in ICE parts manufacturing, it certainly still underscores China's effectiveness and rapid rise to global automotive prominence.[208]

Across the Atlantic, new models of Chinese vehicles are arriving on European shores, the start of an aggressive export drive by manufacturers such as BYD, Chery, Nio, and Great Wall.[209] Six Chinese EVs are now available for purchase in Germany compared to only two a year ago.[210] In late 2022, European rental car giant Sixt announced that it would purchase 100,000 BYD electric vehicles for its European fleet by 2028.[211] If Chinese manufacturers sell 1.5 million vehicles in Europe by 2030, for example, there would be a negative impact of EUR24.2 billion on the wider

[203] Ibid.

[204] 2023 China New Energy Vehicle Initial Quality Study (NEV-IQS). (2023, June 1). J.D. Power.

[205] 2023 U.S. Initial Quality Study (IQS). (n.d.). J.D. Power.

[206] See for example EV price war: China winning, Europe and US losing. (2022, October 6). Fleet Europe; and Electric Car Prices: The Average Electric Car Cost in 2023. Find My Electric.

[207] See for example China's Cutthroat EV Market Is Squeezing Out Smaller Players. (2023, June 26). Bloomberg. and Volkswagen Group China CEO: Electric car market is 'overheating'. (2023, July 6). Autocar.

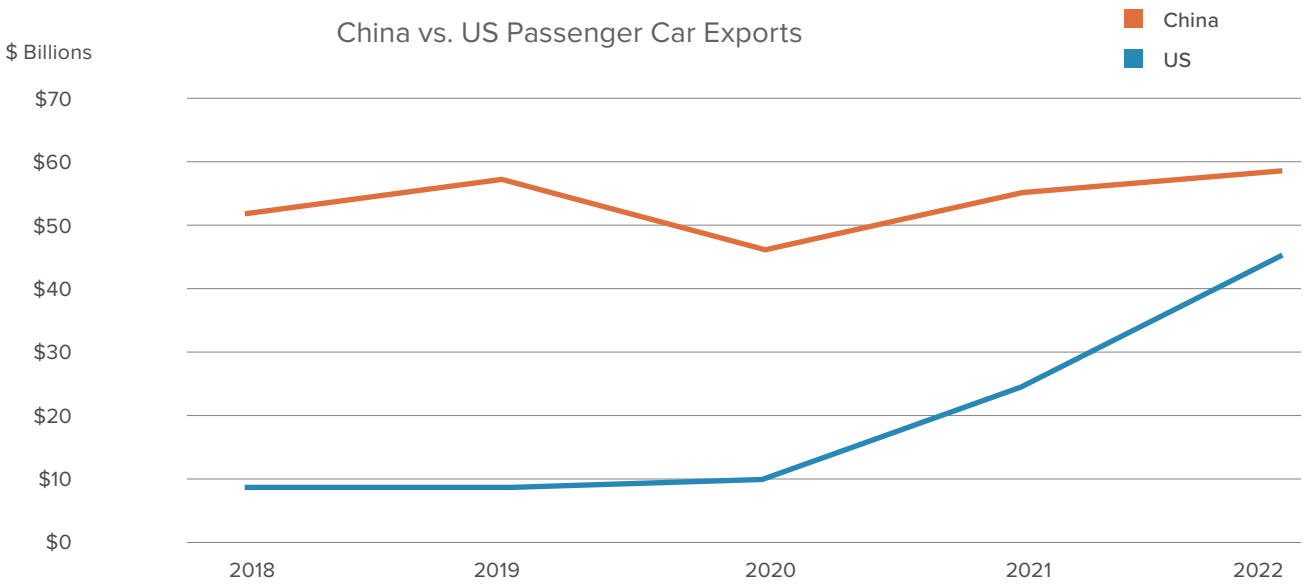
[208] ITC Trade Map. ITC. Retrieved from www.trademap.org.

[209] Li, G., White, E., Nilsson, P., & Campbell, P. (2023, June 29). The Chinese carmakers planning to shake up the European market. Financial Times.

[210] Allianz Research. (2023). The Chinese challenge to the European automotive industry. p 11.

[211] Sixt. (2022, October 4). SIXT and BYD kick-start long-term partnership to boost e-mobility.

Figure 9. Chinese Auto Industry Exports



Source: ReMo analysis based on International Trade Center data.

European economy.[212] KPMG analysis forecast that Chinese auto manufacturers could seize 15 percent market share of new car sales in Europe within the next two years – which is greater than the entire market share of legacy European carmaker Renault.[213]

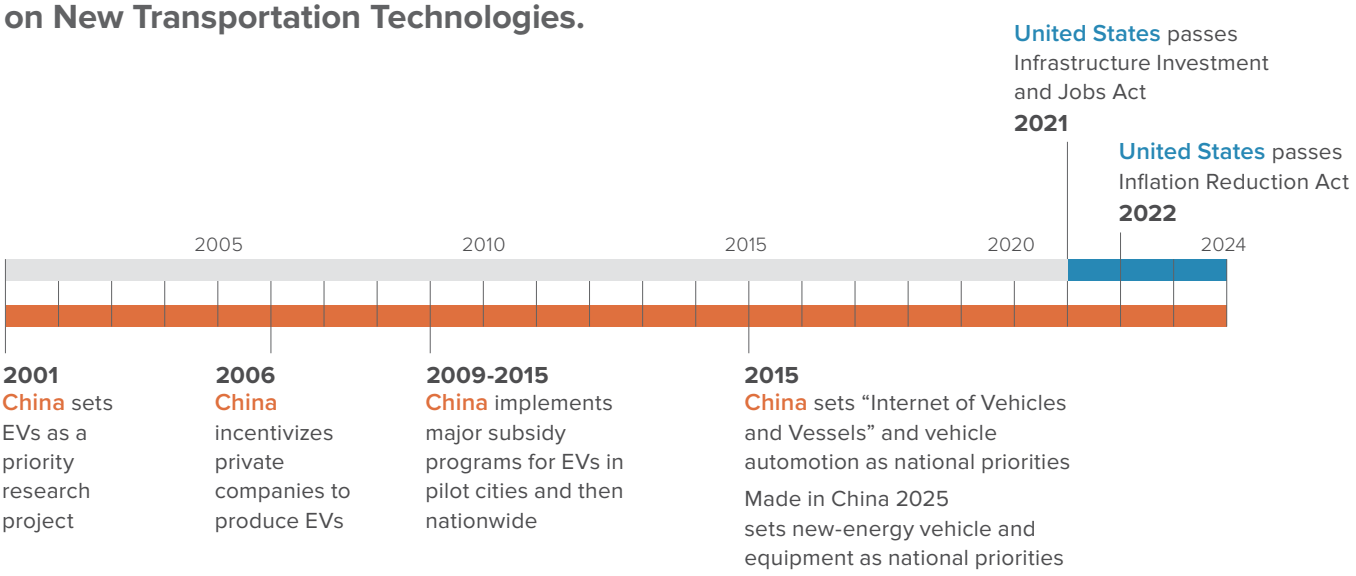
Investment in AVs, Connectivity, and 5G

While EVs receive much of the focus in the media, particularly given China's dominance of critical mineral and battery supply chains, China is poised to solidify a global leadership position in AVs as well. Beijing first identified the AV sector as critical in its 2015 Made in China 2025 document. The following year, China's Ministry of Industry and Information Technology (MIIT) released a roadmap for AV development, which called for half of all domestic vehicles to have driving assist or partially autonomous features by 2020, 10 to 20 percent of vehicles to be highly automated by 2025, and one in 10 vehicles to be fully autonomous by 2030.[214] In 2016, Changan, Ford's state-owned Chinese partner, tested a partially-autonomous vehicle on a successful 1,200-mile drive from Chongqing to Beijing.[215] In June 2017, a group of 98 automakers, universities, and institutes formed a strategic alliance to collaborate on research and standards.[216]

In 2018, China's National Development and Reform Commission (NDRC) unveiled a draft Strategy for Innovation and Development of Smart Cars, which created a framework for technology innovation, industrial and infrastructure development, and regulatory standards.[217] The strategy aims to establish a complete ecosystem for AVs in China, with nearly all new vehicles being "smart" vehicles by 2025; and to become a world leader in the AV industry and infrastructure by 2035.[218] While Beijing often sets aggressive targets that may not be met, it is clear that China has made considerable progress on both the regulatory and technological fronts. In 2018, for example, MIIT created AV road testing rules, setting the groundwork for testing in Shanghai, Guangzhou,

[212]Ibid
[213]Li, G., White, E., Nilsson, P., & Campbell, P. (2023, June 29). The Chinese carmakers planning to shake up the European market. Financial Times.
[214]China Vehicle Engineering Institute. (2016, November 26). Essentials of the Roadmap for New Energy and Smart Vehicle Technology.
[215]See, e.g., Bloomberg News, "Self-Driving Car Completes 1,200-Mile Roadtrip Across China," Bloomberg, April 17, 2016.
[216]See, e.g., Hao Yan, "Auto, tech specialists form alliance to guide future collaborations," China Daily, June 19, 2017.
[217]Eurasia Group, "Chinese AV Ambitions at Risk Amid Trade War," July 9, 2019.
[218]Ibid.

Figure 10: Timeline of Landmark US vs China Policy Actions on New Transportation Technologies.



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13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020). (2015). p 83

Shenzhen, and Chongqing, so that Chinese AV companies would no longer have to test abroad.[219]

China has since risen to the challenge of implementing and scaling connected and autonomous vehicle technology testing and deployment. Beijing, Shanghai, Guangzhou, Wuhan, Wuxi and Changsha, Wuxi were each selected by the Chinese government in 2021 as six pilot cities for the coordinated development of smart city infrastructure and intelligent connected vehicles.[220] Beijing's goal in selecting these pilot cities was to incentivize financial support for the work and to develop replicable and scalable implementation experiences that could be copied by other Chinese provinces and cities.

In the designated intelligent and connected demonstration area in Anting, Shanghai, at least four autonomous-driving companies have commercially road tested between 100 and 200 cars, which is estimated to be more than 10 percent of local e-hailing vehicles.[221] Apollo Go, the autonomous ridehailing subsidiary of Chinese technology giant Baidu, had achieved 1 million autonomous vehicle rides in China by late 2022,[222] and 2 million rides by mid-2023.[223] By comparison, in the United States between 2019 and early 2022 there were just 85,476 total driverless rides.[224] Chinese companies are also setting their sights on overseas markets: the United Arab Emirates recently licensed WeRide to test its

[219]Ibid.
[220]Xhinhua Silk Road Database. (2021, May 8). China pilots intelligent city construction in six cities.
[221]McKinsey & Company. (2023, January 3). Autonomous driving in China.
[222]Johnson, P. (2022, August 30). Baidu's Apollo Go service strikes 1 million EV autonomous rides. electrek.co/2022/08/30/baidus-apollo-go-service-strikes-1-million-ev-autonomous-rides/
[223]Templeton, B. (2023, April 20). Baidu, AutoX Expand Uncrewed Robotaxi Operations In China—Will The World Catch Up? Forbes.
[224]Juliussen, E. (2022, June 3). Waymo vs. Cruise: More Robotaxi Data. EE Times.

Level 4 autonomous vehicles on public roads throughout the country.[225] China's autonomous vehicles market – ranging from automated cargo trucks to robotaxis – is now forecast to reach nearly $100 billion by 2030.[226]

China has also surged ahead in the deployment of 5G technology at scale, largely because Beijing has identified 5G network development as a national priority.[227] 5G technology is a supportive technology that can be used to advance the implementation of connected and autonomous vehicle technology. Its high-speed, low-latency capabilities allow for near real-time communication between vehicles, infrastructure, and other road users. This significantly enhances the ability of autonomous vehicles to navigate and respond to complex road situations.

Unlike in the United States, where mobile phone carriers competitively invest in new technological capabilities according to market signals and scale, Beijing's approach is top-down: the government pledged more than $400 billion in 5G research and development through 2020.[228] The scale of China's investment has been far larger than the United States. By 2020 China had installed at least 350,000 5G sites, compared to fewer than 30,000 in the United States.[229] By the end of 2022, China had installed 2.3 million 5G base stations,[230] compared to just 100,000 in the United States.[231]

Building on momentum over the last several years for the technologies mentioned above, Chinese officials recently announced a major public-private collaboration for the coordinated deployment of autonomous vehicle driving systems and associated infrastructure at scale. In July 2023, the Vehicle-Road Collaborative Innovation Consortium (the Consortium) was launched.[232] This public-private consortium is made up of the China Highway and Transportation Society (CHTS), the China Society of Automotive Engineers (CSAE) the China Institute of Communications (CIC) and more than 70 private companies, including several international automotive and technology companies.

China is leading the US in building 5G Sites

by 2020

350K in China

<30K in the United States

by the end of 2022

2.3M in China

100K in the United States

Sources: Deloitte; Accenture; GSM Association; BDO Global.

[225]Level 4 is a designation by the Society of Automotive Engineers (SAE) that means the vehicle can handle all aspects of driving in certain conditions without any human intervention.

[226]BusinessWire. (2022, October 17). China Autonomous Vehicles Market Report 2022: Featuring AutoX, Baidu Apollo, Didi Chuxing, Pony.ai, TuSimple & WeRide.

[227]Central Committee of the Communist Party of China, The 13th Five-Year Plan for Economic and Social Development of the Peoples' Republic of China 2016-2020, 2015

[228]See, e.g., Dan Littmann et al., 5G: The Chance to Lead for a Decade, Deloitte, 2018, at page 1; and Susan Crawford, "China Will Likely Corner the 5G Market – and the U.S. Has No Plan," Wired, February 2, 2019; and Silvia Amaro, "China is vastly outspending the U.S. on 5G infrastructure, expert says," CNBC, November 18, 2019.

[229]See, Dan Littmann et al., 5G: The Chance to Lead for a Decade, Deloitte, 2018, at page 1; and Accenture Strategy and Accenture Network Practice, Impact of Federal Regulatory Reviews on Small Cell Deployment, Accenture, March 12, 2018.

[230]GSM Association. (2023, March 26). GSMA Mobile Economy China Report Forecasts China will be first market in the world to reach 1BN 5G Connections by 2025.

[231]Mannion, T. (2022, October 25). What is the impact of the U.S. lagging on 5G? BDO Global.

[232]China Highway & Transportation Society. (2023, August 1). The Vehicle-Road Collaborative Innovation Consortium established three national societies to jointly promote the integrated development of vehicle, road and cloud. www.chts.cn/xw/XHDT/art/2023/art_27fb7fca14e444a7a2b3765a69c15507.html

China has built a major **public-private collaboration**

for the coordinated deployment of autonomous vehicle driving systems and associated infrastructure at scale. Deployment will take place across four major inter-city corridors:

BEIJING-TIANJIN-HEBEI

SHANGHAI-NANJING-HANGZHOU

GUANGZHOU-SHENZHEN

CHENGDU-CHONGQING

Source: "Is China the Future of AVs?" presentation by Professor Bin Ran, Transportation Research Board Automated Road Transport Symposium, July 2023

There are three pillars of the Consortium – deployment of autonomous vehicles and supporting infrastructure on freight corridors, on freeway corridors, and in selected smart cities. Deployment will take place across four major inter-city corridors across the east of China: the Beijing-Tianjin-Hebei region; Shanghai-Nanjing-Hangzhou (Yangzhi Triangle); Guangzhou-Shenzhen (Zhu Triangle) and Chengdu-Chongqing.[233] Funding for the consortium project will come from the Chinese government, private sector funding via a special purpose vehicle, and venture capital funding.

The ambitious public-private investment in the Consortium is in stark contrast to the current funding and investment environment for AVs in the United States, which has seen consolidation and dissolution of key companies in the space.[234] Private sector investment in robotaxi and automated delivery operations is evaporating in the United States, dropping 60 percent in 2022 compared to the previous year.[235] There is a very real risk, given the lack of any ambitious federal policy on AVs in the United States, that capital investment will dry up before the technology can be fully commercialized. In a changing competitive landscape where China is playing – and spending – to win, a failure to prioritize AV development could mean that the United States has already ceded technology leadership to China.

China now leads the world across autonomous, connected, electric, and shared vehicle manufacturing, deployment, testing and sales, as well as transportation infrastructure investment, thanks to its bold industrial policies across these diverse areas. China is firmly on a path to reaping the rewards of market domination of nearly all advanced mobility systems, as well as their supply chains, and of the economic prosperity these innovations and investments will facilitate. While the United States and its allies engage in siloed insular debates and transportation culture wars about the merits of new transportation technologies, China is quickly cementing its position as the leader in many important and economically valuable advanced mobility technologies.

The Risks of China's Dominance of New Vehicle Technologies

Beijing's dominance of electric, connected, and autonomous vehicles poses a range of risks that U.S. policymakers and industry should consider. First, connected, and autonomous vehicle technologies, including the artificial intelligence algorithms underpinning them, are relatively nascent innovations with massive commercial potential. If Chinese companies and state-linked entities gain global dominance of valuable intellectual property rights associated with these technologies and ultimately export that technology to the United States, they potentially have leverage to exert control over critical infrastructure technologies as they are deployed in the United States and allied markets.

[233] "Is China the Future of AVs?" presentation by Professor Bin Ran (Transportation Research Board Automated Road Transport Symposium, July 2023)

[234] See for example Ford, Volkswagen-backed Argo AI to shut down. (2022, October 26). Reuters. and Ho, J. (2019, January 16). The next stage of the AV industry: Consolidating and refocusing. Axios.

[235] Hawkins, A. J. (2023, April 25). Cruise continues to burn GM's cash as robotaxis expand to daylight hours. The Verge.

High-Speed Rail & Other Infrastructure

Fu Zhihuan, the highly respected former Chinese Minister of Railways who steered the impressive development of Chinese high-speed rail in less than two decades, is now leading the Vehicle-Road Collaborative Innovation Consortium, discussed earlier in the report, to accelerate deployment of AVs and supporting infrastructure. From humble beginnings in 2008, with a single 85-mile line between the cities of Beijing and Tianjin, in just 15 years China has built the world's largest high speed rail network that spans nearly 25,000 miles, with plans to grow coverage to 31,000 miles in 2025 and 125,000 miles by 2035.

China's high-speed network is now 13 times the size of Japan's Shinkansen bullet train network. This is an impressive feat given that China is, geographically, approximately the same size as the United States. China is pouring money nationwide into transportation fixed-asset investments, with a record 3.8 trillion yuan ($537 billion) invested in 2022 alone as part of China's current five-year social and economic development plan. The World Bank has found that China's high-speed network has delivered an 8 percent economic return, well above the opportunity cost of capital in China and most other countries for major long-term infrastructure investments.

As well as providing vital transportation links to its population, Chinese officials understand the economic and employment benefits of these kinds of ambitious policies and levels of investment. In February 2023 Vice Transport Minister Xu Chengguang said "transportation infrastructure investment involves large outlays that yield quick economic benefits and can create jobs … we'll expand investment to support an economic turnaround." In fact, the positive economic ripple effects of large scale transportation investment can often exceed expectation.

For example, the forecasts of the U.S. Interstate Highway System's impacts significantly under-estimated demand. By 1965, the number of vehicles traveling on the network and the vehicle miles traveled (VMT) served were 11 and 9 percent higher than estimated, respectively. The Interstate Highway System also contributed to a Gross Domestic Product (GDP) that significantly performed above forecasts for that period.

China's own expressway system developed much later than the United States' interstate system, but at a much faster pace and at a much greater scale. China had no highways at all before 1989, but by 2011 the Chinese expressway system surpassed the U.S. Interstate in size. Unlike the U.S. Interstate, which was funded through fuel taxes, almost all Chinese expressways are toll roads financed by private companies under contract from provincial governments, commonly as public-private partnerships. This public-private partnership approach was chosen to facilitate the fast construction of the system. The rationale by Chinese officials for this intensive infrastructure development has always been economic – simply put, highway construction creates jobs and nurtures related industries.

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LiDAR: A priority technology for national security

LiDAR stands for Light Detection and Ranging. This technology is a remote sensing method that uses light in the form of a pulsed laser to measure distances to objects. These light pulses, combined with other data recorded by the vehicle that the LiDAR sensors are attached to, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Key for Civilian Uses

LiDAR is critical to reimagined (civilian) mobility because most vehicles with autonomous capabilities use LiDAR sensors to detect and avoid obstacles, map their surroundings, and navigate roads safely. LiDAR is also used as part of ADAS systems, helping with object detection and collision avoidance, pedestrian detection, lane assistance, adaptive cruise control and parking assistance.

- Most civilian vehicles with autonomous capabilities use LiDAR sensors

Crucial for National Security

However, there are also extensive military applications for LiDAR technology. In fact, the U.S. military was the first to explore the potential of LiDAR technology during the Cold War, for reconnaissance and terrain mapping purposes. Today, LiDAR is used by militaries for 3D tactical mapping, determining line of sight, naval warfare, and for navigation by military autonomous vehicles. For example, unmanned ground support vehicles to carry supplies, conduct medical evacuations or undertake armed reconnaissance.

LiDAR is relevant to a number of the fields of technologies identified as being particularly important to the national security of the United States on a Critical and Emerging Technologies List, which was prepared by the National Science and Technology Council. Specifically, LiDAR is used in the fields of sensor processing and data fusion, adaptive optics, remote sensing of the Earth, security-sector sensing and environmental-sector sensing – as well as transportation-sector sensing.

- LiDAR is also used by militaries for 3D tactical mapping, determining line of sight, naval warfare, and for navigation by military autonomous vehicles.

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https://ts2.space/en/the-history-of-lidar-technology-from-military-applications-to-everyday-use/#:~:text=The%20United%20States%20military%20was,strategic%20planning%20and%20intelligence%20gathering.

https://www.whitehouse.gov/wp-content/uploads/2022/02/02-2022-Critical-and-Emerging-Technologies-List-Update.pdf

Chinese public authorities and businesses might also have leverage to engage in coercive or restrictive practices, limiting access by U.S. and allied nations' firms to critical digital infrastructure. American firms operating in China already persistently report discrimination in licensing intellectual property.[236] As geopolitical tensions between China and the United States and its allies increase, it is highly feasible that international firms operating both inside and outside of China risk facing greater discrimination in licensing necessary IP, turning patents into weapons. Chinese companies are now reported to be in a position where they can "keep other companies out of business" in the connected automotive sector.[237]

Beijing has a long history of enabling unfair and coercive practices by Chinese companies in relation to intellectual property of novel transportation technologies. This includes LiDAR, a remote sensing method using pulsed laser light to measure distance, speed, and altitude. Chinese LiDAR firms have benefited from generous industrial policies and subsidies, active discrimination by the Chinese state against U.S. and allied nation firms that are active in LiDAR research, and aggressive acquisition of foreign intellectual property that has involved questionable practices and in some cases illicit activity.[238] San Francisco-based LiDAR maker Ouster recently launched a patent infringement claim against its Chinese rival Hesai Inc, alleging that the Chinese firm "stole Ouster's revolutionary patented technologies and incorporated them into Hesai's competing products."[239] Ouster is the new owner of U.S. firm Velodyne, which previously attempted to sue Hesai for alleged theft of its patented LiDAR technologies.[240] With Chinese firms now holding 58 percent of global market share in the automotive LiDAR segment, the CCP is considering imposing an export ban on LiDAR technologies, underlining this technology's strategic importance.[241]

Second, the data generated by connected and autonomous vehicles systems is a form of digital infrastructure. If China, through its companies and state-linked entities, dominates both the relevant intellectual property of these systems and the global race to scale AV deployment, this would give Chinese companies access to vast amounts of valuable and sensitive data.

Access to this data poses privacy and data security risks. While not explored in detail in this report, the data generated by patented autonomous transportation innovations also fuels the iterative development and machine-based learning of autonomous vehicle systems. Vehicles with autonomous technology generate between 25 gigabytes to 19 terabytes of data per hour.[242] Data generated by vehicles – and the right to commercially exploit the value of that data – has been effectively owned by the vehicle or technology manufacturer, in other words, the intellectual property patent holder or licenser of that technology.[243] Chinese dominance of AI patents associated with autonomous transportation technology could therefore facilitate Chinese dominance of the "fuel" for further scientific development.

***Chinese dominance of AI patents associated with autonomous transportation technology** could facilitate Chinese dominance of the "fuel" for further scientific development.*

[236]2021 Business Climate Survey. (n.d.). AmCham China. and Zhang, T. (2023, March 5). 2023 China Business Climate Survey Report. AmCham China.

[237]Espinoza, J., Gross, A., & Nilsson, P. (2023, April 29). Carmakers raise concerns at Chinese dominance over connectivity patents. Financial Times.

[238]Ibid.

[239]Adler, A. (2023, April 12). Lidar maker Ouster sues China's Hesai for patent infringement. FreightWaves.

[240]The Commanding Heights of Global Transportation. (2020). SAFE. p 60.

[241]Zhang, S. D., Yuan Yao, Jack. (2023, April 5). China's Proposed Export Ban on LiDAR Technology: What Impact Will It Have on the Automotive Industry? AlixPartners.

[242]Wright, S. (2021, July 2). Autonomous cars generate more than 300 TB of data per year. Tuxera. and The Data Deluge: What do we do with the data generated by AVs? (2021, January 22). Siemens.

[243]Zhang, S. (2018). Who Owns the Data Generated by Your Smart Car? Harvard Journal of Law & Technology, 32(1).

Further, this sensitive data is at risk of disclosure to the state – China is a country where businesses are expected to comply with CCP wishes, surveillance is ubiquitous, and individuals' privacy are not protected.[244]

Third, China is rapidly translating its dominance of connected and autonomous vehicle technologies into influence over global standards and norms in this field, which will affect the trajectory of the entire transportation transition. China has long engaged with international standards development as a way of improving Chinese standards to facilitate trade and improve market access for its businesses. However, China's engagement in international standards bodies, such as ISO, has increasingly become focused on influencing international standards development to pave the way for Chinese influence in areas of Chinese competitiveness.[245] For example, China recently led the development of an international standard for autonomous driving test scenarios, which defines concepts in autonomous driving tests and results in a standardized language.[246]

Increasing Chinese dominance of intellectual property and know-how in this field – through fair means or foul – therefore ***could meaningfully impact U.S. military capabilities and its future ability to project power and maintain a global rules-based order.***

Finally, autonomous transportation technology developed in a civil context also has potential military applications. U.S. and Chinese forces both use LiDAR, to support autonomous navigation capabilities for uncrewed ground and aerial vehicles.[247] A LiDAR technology industry association recently warned that the technology could be used to harvest copious amounts of sensitive data about U.S. infrastructure and could be used by Chinese firms on military vehicles to make them self-driving.[248]

Increasing Chinese dominance of intellectual property and know-how in this field – through fair means or foul – therefore could meaningfully impact U.S. military capabilities and its future ability to project power and maintain a global rules-based order. This is in addition to the negative impact on U.S. economic competitiveness in civil applications of LiDAR technologies. Further, the CCP has an ambitious Military-Civil Fusion (MCF) national strategy, which has the aim of enabling China to develop the most technologically advanced military in the world. Key technologies that are being targeted under the MCF include artificial intelligence and big data,[249] both of which underpin connected and autonomous vehicle development.

Ultimately, continued procrastination by the United States and allies on the issue of advanced transportation technologies and a failure to implement coordinated government policy in partnership with the private sector effectively concedes defeat on multiple fronts to an ambitious and focused Beijing.

[244]Wakabayashi, D., Chang, C., & Fu, C. (2022, October 17). In Xi's China, the Business of Business Is State-Controlled. The New York Times.
[245]Seaman, J. (2020). China and the New Geopolitics of Technical Standardization. Institut français des relations internationales. p 22
[246]Road vehicles. (n.d.). ISO 34501:2022. ISO.
[247]Sutter, K. M., & Sayler, K. M. (2023). U.S.-China Competition in Emerging Technologies: LiDAR. U.S. Congressional Research Service.
[248]Turton, W. (2023, July 26). Fears of Chinese Self-Driving Car Tech Are on the Rise. Bloomberg.
[249]Military-Civil Fusion and the People's Republic of China. (2020). U.S. Department of State.

Overcoming Challenges and Revolutionizing Transportation

Over the past three years it appears the United States and its allies may finally have woken up to the reality that without bold policy actions, China will be allowed to dominate – unchecked – the enabling materials, manufacturing, and intellectual property required for the transportation and energy transitions.

Policymakers have taken first steps in the right direction to address China's dominance of new transportation technologies and have created new industrial policy strategies targeted to the challenges building out domestic and allied industries in this space. The passage in 2022 of the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law (BIL) was an unprecedented reinvigoration of U.S. industrial policy, promising $700 billion in infrastructure, research activities, and related programs relevant to transportation technologies, particularly electrification. In 2023, the European Union unveiled its Green Deal Industrial Plan and a proposal for a Net Zero Industry Act.

U.S. and allied industry have reacted quickly in response to the opportunities provided by these policy actions. This serves as evidence that just as was the case in China, bold targeted policy action and public investment are effective and possibly required mechanisms to stimulate private sector investment and business activity.

As a front and center example, the International Energy Agency (IEA) reports that, as a direct result of the IRA, between the period of August 2022 and March 2023 major EV and battery makers announced cumulative post-IRA investments of at least $52 billion in North American EV supply chains.[250] The Financial Times recently calculated that

[250]Executive summary – Global EV Outlook 2023 – Analysis. (n.d.). IEA.

As a direct result of the **Inflation Reduction Act,**

Between the period of August 2022 and March 2023 major EV and battery makers announced cumulative post-IRA investments of at least

$52 BILLION

in North American EV supply chains.

$200+ BILLION

worth of projects have been promised since the passage of the IRA and the CHIPS Act, which will lead to the creation of as many as

85,000 JOBS

Source: Chu, A., Politi, J., & Brower, D. (2023, July 12). The new era of big government: Biden rewrites the rules of economic policy. Financial Times.

more than $200 billion worth of projects have been promised since the passage of the IRA and the CHIPS Act, which will lead to the creation of as many as 85,000 jobs.[251] Consumers have also embraced the new range of electrified transportation choices offered. EV sales in the United States increased 55 percent in 2022, reaching a sales share of 8 percent.[252]

Yet the full potential of advanced transportation technologies cannot currently be realized in the U.S. and allied markets because policymakers have not fully prioritized autonomous, connected, electric, and shared vehicle technologies to the same extent as Chinese policymakers. Specifically, the significant investments in the IRA and BIL are focused on the electric vehicle value chain – mining of raw materials, processing of fuels, and vehicle and component manufacturing.[253]

Far less financial firepower and direct policy attention has been given to connected and autonomous vehicle technologies and their convergence with digital communications technologies that are now a core fabric of our everyday lives. For example, there is relatively limited federal policy direction given to states, transit agencies, and other local authorities to prioritize the kinds of capital investments that would accelerate autonomous, connected, electric, and shared vehicle technologies. And apart from a few select policy packages, current federal policy does not prioritize long-term investments in either state of good repair or new technologies.[254] While recent landmark U.S. legislation helps the nation to start catching up to China in areas where the lead has been ceded, such as electric vehicles, critical long-term investments in other areas of advanced transportation technologies are not being given equal attention.

Learning lessons from China's success in prioritizing autonomous, connected, and electric vehicle technologies and its convergence with digital communications technology does not mean replicating Chinese policies. China is an authoritarian one-party state, with a socialist market economy, under the unified control of the CCP. For all of China's impressive successes in transforming itself in a few short decades to its current position as the world's second largest economy,[255] it remains a fascist state with a vastly different world view to that of democratic capitalist nations. In China's socialist market economy, successful businesses are required to conform to the aims of the CCP.[256]

[251]Chu, A., Politi, J., & Brower, D. (2023, July 12). The new era of big government: Biden rewrites the rules of economic policy. Financial Times.

[252]ibid

[253]Tomer, A. Will the infrastructure law and Inflation Reduction Act transform American transportation? It's complicated. (2022, November 1). Brookings.

[254]Such as the programs for EV Charging Networks and Alternative Fuel Corridors under the BIL, and other programs such as the Strengthening Mobility and Revolutionizing Transportation (SMART) grant program.

[255]According to 2022 World Bank data, the United States is the world's largest economy with gross domestic product (GDP) of $25,462 billion. The People's Republic of China is the world's second largest economy with GDP of $17,963 billion. See World Bank Open Data from data.worldbank.org

[256]Wakabayashi, D., Chang, C., & Fu, C. (2022, October 17). In Xi's China, the Business of Business Is State-Controlled. The New York Times.

THREE COUNTERINTUITIVE TRUTHS

1. **Automated vehicle technology** is closer than it may appear.
2. **Digital technology** is mobility technology.
3. **Electrification is critical,** but we must also optimize for purpose-built, resource-efficient new mobility.

In order for the U.S. and its allies to recapture the lead from China on mature transportation mobility and its convergence with digital communications technology, it is necessary to leverage the same factors that enabled the automobile transportation system's ability to massively expand freedom and economic opportunity through transportation, that also built the strength of the U.S. technology sector.

The growth of that private sector-led industry was supported and enabled – but not controlled – by the system dynamics and feedback loops favoring the automobile that flowed from supportive U.S. federal policies such as the development of the Interstate Highway System via the Federal Highway Act of 1956. In other democratic nations, it will be imperative to consider their unique economic and political strengths to plot the most effective roadmap to advance their own development, testing and deployment of these innovative and modern technologies.

Meanwhile, the growth of Silicon Valley ingenuity was facilitated by the convergence of reliable defense funding, a large pool of skilled engineers and scientists from around the world studying at local universities, academic leadership, and a network of venture capital firms.[257] According to the World Intellectual Property Organization, the San Francisco-San Jose region is one of the world's top five science and technology innovation clusters, and the United States ties with China for hosting the greatest number of these clusters (21 in each country).[258]

To compete with an authoritarian, top-down global peer in China, the United States should double down on a market-led approach to enabling freedom through a reimagined mobility system and digital communications technology – one that is unequivocally supported by federal policies that impact underlying system dynamics and technology innovation opportunities.

To leverage these factors, U.S. policymakers must first grapple with three counterintuitive truths about the technologies and industries critical to a reimagined mobility system and people's freedom to move.

First, automated vehicle technology is closer than it may appear. However, the pathway to adoption must be more human-focused than it currently is to realize the full benefits of this technology. This means leaning into full autonomous vehicle deployment in the use cases to which this technology is best suited and prioritizing the quicker near-term scaled deployment of advanced driver assistance systems. Particularly deployments that build consumer trust and generate consumer demand.

Second, digital technology is mobility technology. Connectivity affects the trips people choose to take as well as those they opt to forgo. Those avoided trips – the nega-miles – are important to consider when looking at the larger transportation system. The convergence of mobility and digital connectivity must be leveraged for greater convenience, reach, reliability, and resilience of mobility systems.

Third, electrification is critical, but a reimagined mobility future must also optimize for purpose-built, resource-efficient new mobility in the transportation system by enabling more diverse form factors and use cases. Government planning and funding must adapt and support these, by allowing and incentivizing the market to provide more diversity of vehicle options and mobility services that are better tailored to the distinct types of trips people make. An extended cab truck may be the right vehicle for hauling lumber, but it is extremely inefficient for a quick trip to the store.

Despite being home to a tremendous number of innovative companies that have made significant strides in mature transportation mobility and digital communications technologies, the United States now finds itself lagging behind

[257]Castells, M. (2010). The Rise of the Network Society. Wiley. p. 52
[258]WIPO. (n.d.). Global Innovation Index 2022, 15th Edition.

The assembly plant of the Bell Aircraft Corporation at Wheatfield, NY, 1940s

China in many parts of the critical sectors of connected and autonomous vehicle technologies. This is not due to a lack of American technological ingenuity or enterprise; rather, it is an issue rooted in the political landscape and siloed approaches to policy.

Polarized political debates and incoherent, conflicting policies have proven to be major roadblocks, stunting the ability of these innovative companies to scale up their products. This is compounded by consumer, investor, and workforce skepticism of the true potential and benefits of new mobility technologies, and systemic barriers in areas as diverse as industrial and employment policy, supply chains, funding climates, and insurance.

A failure to take meaningful, coordinated action to overcome the challenges risks a potential loss of jobs, reduced innovation, and a less competitive economy in the industries that will define global growth in coming decades. Passivity by policymakers, the private sector and the public on these issues also risks a failure to unlock the benefits of these innovations and missing the opportunity to address major challenges of our time.

An interesting historical contrast are the coordinated efforts taken by the U.S. with the transportation sector during the Second World War, as part of efforts to quickly mobilize all industries and expand productive facilities.[259] This experience in the development and use of American industrial capacity is remembered as the classic case of economic mobilization to support the nation and its allies.[260] Applicable lessons for today from this period are the value of central coordination and leadership, the extensive use of public-private partnerships, consistent national messaging and public engagement, extensive research and development investment, using regulation and incentives to steer outcomes, a willingness to be adaptable and the importance of cooperation and building alliances with like-minded partners.[261]

To secure its position as a global leader in the connected and autonomous arena and catch up with China, the United States needs a clear, unified, and forward-looking policy approach. ReMo proposes that immediate attention be paid to specific challenges, fostering an environment where American innovation can truly flourish. In future work, ReMo will analyze in greater detail the potential of mobilizing the transportation sector to ensure the economic and national security of the United States and its allies.

By implementing bold action, not only will this propel the United States to the forefront of the convergence of new mobility technologies with digital communications technology, but it will also democratize transportation, giving people unprecedented freedom to move – from everyday commuting to opening up new opportunities for those currently limited by conventional vehicle operation.

[259]WWII: Mobilization. (n.d.). U.S. Army Center of Military History.

[260]Ibid

[261]See for example Herman, A. (2012). Freedom's forge: How American business produced victory in World War II (1st ed). Random House.

Credit: Library of Congress, Prints & Photographs Division, FSA/OWI Collection

Challenges to U.S. Leadership in Mobility Technologies

While the benefits are compelling, there are clear and concrete challenges to achieving reimagined mobility. Several of these challenges relate to the existing policy environment that directly and indirectly shapes and impacts the transportation and energy sectors. The current system lacks resilience and the ability to meet the rising strength of China's energy and transportation industries.

ReMo has identified that bold actions across a range of policy areas would help address the current challenges of achieving a reimagined mobility system. Some of these challenges involve reforming existing policy regulatory frameworks that – although well-intentioned – have curbed the potential of connected and autonomous mobility innovation. Some challenges need policy reforms, while others require a completely new policy framework to harness the potential of modern mobility technologies and to counter China's market control.

Beyond policy, there are other challenges to achieving this future – they involve consumer behavior and acceptance, private sector activity, and the business factors that support this innovation. Policy is not determinative of all outcomes, but it can have an especially important direct and indirect influence on people's personal choices and business and investment outcomes. For example, consumer tax credits for the purchase of EVs have been proven in the United States to boost consumer sales by up to 53 percent in some areas, long after the expiration of the tax credit program.[262] Meanwhile, the IRA and BIL have stimulated billions in private sector investment in electric vehicle and battery manufacturing, and as noted previously, decades of U.S. federal policies on fuel economy, vehicle design and safety standards have influenced the transportation landscape. Therefore, to effectively reimagine mobility, it is critical to consider the interplay of policy, consumer behavior, and business and investment realities. For example, how does national regulatory certainty for testing and scaling impact the ability to monetize or secure funding?

Supply Chain Challenges

As part of China's strategically executed dominance of new mobility technologies, China exerts considerable influence over nearly every step of the global EV supply chain. This includes the global mining and chemical processing of critical minerals; the production of anodes, cathodes, and lithium-ion cells for batteries; and the manufacturing of vehicles and their components.[263]

Specifically, the United States and its allies face clear and present challenges in the control of the components and minerals essential to the development of advanced transportation innovation such as autonomous vehicle technologies. The CCP perceives leadership in AI and its applications to be foundational to the future of its economic and military power.[264] There is major ongoing geopolitical tension between China and the United States and its allies for control of the underlying semiconductor chips industry and their associated supply chain that powers AI applications and indeed all modern electronics and digital communications.[265]

In retaliation for U.S., Dutch, and Japanese export controls on semiconductor manufacturing equipment, the Chinese

Consumer tax credits for the purchase of EVs have been proven in the United States to ***boost consumer sales by up to 53 percent in some areas, long after the expiration of the tax credit program.***

[262]He, C., Ozturk, O. C., Gu, C., & Chintagunta, P. K. (2023). Consumer Tax Credits for EVs: Some Quasi-Experimental Evidence on Consumer Demand, Product Substitution, and Carbon Emissions. Management Science. and Want Consumers to Buy Electric Cars? Give Them Tax Credits. (n.d.). The University of Chicago Booth School of Business.

[263]Horowitz, J., & Coffin, D. (2018). The Supply Chain for Electric Vehicle Batteries. SSRN Electronic Journal.

[264]Allen, G. C. (2023). Blocking China's Access to AI Chips Matters to U.S. National Security.

[265]See Allen, G. C. (2023). China's New Strategy for Waging the Microchip Tech War.

Both gallium and germanium are essential to advanced chip development, and ***China controls 80 percent of the total global production of gallium, and 60 percent of the total global production of germanium.***

government in July 2023 implemented retaliatory export controls on exports of the minerals gallium and germanium, and three months later on graphite.[266] These minerals are essential to advanced chip development, and China controls 80 percent of the total global production of gallium,[267] and 60 percent of the total global production of germanium.[268] Gallium and germanium are listed as two of the critical minerals or raw materials crucial to both the United States'[269] and Europe's[270] economies. Chinese dominance of the global supply of these minerals and aggressive export control policies were prioritized because these metals are used in the kind of high-speed computer chips central to connected and autonomous vehicles among other innovative modern technologies. Volkswagen has stated that both minerals play a role in autonomous driving functions.[271] It is not a coincidence that connected and autonomous vehicle technologies also have dual civilian and military applications, which means that any ability for China to manipulate or cut off the supply of materials required for their development directly impacts the ability of the United States and its allies to protect themselves at home and abroad.[272]

Despite the CCP's current dominance of critical mineral and battery supply chains, their ultimate leadership position is not inevitable. As noted in SAFE's 2023 report *A Global Race to the Top: Using Transparency to Secure Critical Mineral Supply Chains*, many countries, including the United States, sense an opportunity to regain a competitive advantage from China. The United States, Canada, Australia, and the European Union are beginning to examine policies and implement sweeping legislation to incentivize upstream production and downstream demand to fuel investments in domestic mining, processing, manufacturing, and recycling in an attempt to insulate themselves from dependency on Beijing.[273] However, these efforts are likely to fall short without more coordinated action among the United States, its allies, and partners.

As the transition from an oil-based to a minerals-based economy accelerates, the concept of energy security will shift. An economy run on fossil fuels requires a constant and continuous flow of material that combusts one time to generate energy.[274] Batteries based on critical minerals differ from oil, gas, coal, and nuclear energy in that they can be reused. Therefore, the capability to commercialize and repurpose these materials and technologies will play a pivotal role in ensuring energy security for the 21st century.

However, a clear roadblock in the U.S. economy is its ability to "make-use-recycle" more critical minerals that are already in circulation.[275] Critical minerals are already used in a number of important defense, medical, and transportation technologies, yet the United States and its allies lack a comprehensive

[266]China to restrict exports of chipmaking materials as US mulls new curbs. (2023, July 4). Reuters.

[267]Gallium. (n.d.). CRM Alliance.

[268]Germanium. (n.d.). CRM Alliance.

[269]What Are Critical Materials and Critical Minerals? (n.d.). Energy.Gov.

[270]Critical raw materials. (n.d.). European Commission.

[271]Companies respond to China's curbs on gallium and germanium exports. (2023, July 7). Reuters.

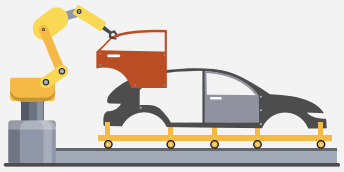
[272]See for example Lewis, J. A. (2021). National Security Implications of Leadership in Autonomous Vehicles. and Guntrum, L. G., Schwartz, S., & Reuter, C. (2023). Dual-Use Technologies in the Context of Autonomous Driving: An Empirical Case Study From Germany. Zeitschrift Für Außen- Und Sicherheitspolitik, 16(1), 53–77.

[273]A Global Race to the Top Using Transparency to Secure Critical Mineral Supply Chains. (2023). SAFE. p 17.

[274]Ibid, p 39.

[275]Adler, A.R. (2022, May 19). Recycling critical minerals is an underappreciated national security tool. The Hill.

Figure 11. Circular Economy in Automotive Manufacturing.



MATERIALS & MANUFACTURING

USE PHASE

Efficient Production
Minimized waste during the manufacturing process, using less energy and water.

Recycled Inputs
Use of recycled or bio-based materials for parts, reducing the need for virgin raw materials.

Maintenance and Repairs
Keeping the vehicle in good condition to extend its life and reduce the need for a new car.

Design for Durability
Constructing vehicles to last longer, reducing frequency of replacement.

Shared Mobility
Encouraging car-sharing or pooling to maximize the use of a single vehicle, reducing the overall number of vehicles needed.

Circular Economy in Automotive Manufacturing

Modular Design
Designing cars to allow for easy replacement or upgrading of parts, rather than discarding the entire vehicle.

Eco-Driving
Practices and technologies that optimize fuel consumption and reduce emissions.

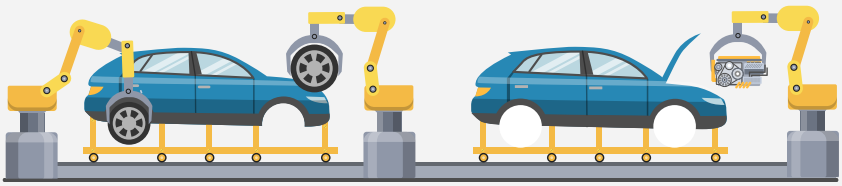
Dismantling and Recycling
Taking apart the car to recover valuable materials and components to be re-used.

Safe Disposal
Ensuring that any non-recyclable parts are disposed of in an environmentally-friendly manner.

Battery Recycling and Repurposing
Minerals can be extracted from used EV batteries. And many can be repurposed, extending their lifecycle.

Repurposing
Rather than being discarded, parts of old cars can be used for new purposes.

END-OF-LIFE PHASE



Source: Aguilar Esteva, L. C., Kasliwal, A., Kinzler, M. S., Kim, H. C., & Keoleian, G. A. (2021). Circular economy framework for automobiles: Closing energy and material loops. Journal of Industrial Ecology, 25(4), 877-889.

recycling apparatus to collect, transport, and reprocess batteries, components, and equipment. Rather, these vital commodities sit inside junk drawers, landfills, or are exported for reprocessing. This inhibits the United States' and its allies' ability to extend the lifespan of materials and maintain a secure supply of concentrates, oxides, alloys, components, cells, and the batteries themselves.[276]

Transitioning to a circular business model in the automotive sector is the sort of moonshot aspirational goal that presents a unique set of challenges that go beyond traditional manufacturing norms. Primarily, the deeply entrenched linear manufacturing model – which hinges on "take-make-dispose" principles – makes any paradigm shift both culturally and operationally arduous. The intricacies of automotive supply chains, characterized by myriad components, materials, and processes, can make the tracking and repurposing of materials a challenging endeavor. Additionally, there are significant technological hurdles in efficiently recycling and reusing certain car components, especially given the increasing integration of electronics and the varied lifespan of various parts.[277]

Regulatory barriers, consumer perceptions, and the initial economic implications of adapting to a circular model further compound these challenges. Despite these obstacles, the push towards circularity is imperative, not only for environmental sustainability but also for long-term economic resilience and industry innovation. In addition, circularity can enhance national security. Once the United States and its allies have the resources they need above ground, this reduces the reliance on volatile extraction and processing. A circular automotive value chain could reduce carbon emissions by up to 75 percent as well as resource consumption by up to 80 percent per passenger kilometer.[278]

Funding and Investment Challenges

Over recent years, the excitement and promise surrounding advanced driver assistance and autonomous vehicle technologies have faced setbacks. Initially hailed as the imminent future of transportation, the deployment of these technologies has taken longer than industry insiders and enthusiasts had initially projected – despite huge advancements made in the underlying technology. This protracted development timeline has led to a wavering of investor confidence, with many redirecting their capital towards more immediately lucrative opportunities. Various challenges, ranging from, the complexity of the technology, regulatory hurdles, and safety concerns, to the intricacies of human-machine interaction, have prolonged the R&D phase. As a result, the investment momentum that once propelled these technologies forward has dried up in recent years.

Global economic uncertainty due to the pandemic, geopolitical instability, the conflict in Ukraine, soaring inflation, and intense energy challenges in Europe and other regions has meant there is a reduced pool of funding for groundbreaking technologies in general, including autonomous mobility.[279] This challenging investment reality puts significant strain on participants in the autonomous vehicle space to progress their technological offerings and deliver profitable service sooner. For example, although cost per mile parity for robotaxis is expected by 2030, the cost to customers of robotaxis is expected by 2025 to be around 2.25 times the cost of existing ridehailing services.[280] However, the profitability of existing ridehailing services – which like many new mobility services, operate without public subsidy – is far from certain. Market research has shown that the costs for robotaxis to break even in different countries would be US$0.28 per mile (China), US$0.38 per mile (UK) and US$0.42 per mile (U.S.).[281]

[276]A Global Race to the Top Using Transparency to Secure Critical Mineral Supply Chains. (2023). SAFE. p 39

[277]See for example Vanegas, P., Peeters, J. R., Cattrysse, D., Tecchio, P., Ardente, F., Mathieux, F., Dewulf, W., & Duflou, J. R. (2018). Ease of disassembly of products to support circular economy strategies. Resources, Conservation and Recycling, 135, 323–334.; Furchgott, R. (2022, August 31). Some Carmakers Say Recycling Car Parts Is the Future. But Is It Realistic? The New York Times.

[278]Ben Dror, M., Gupta, A., Deloison, T., Schmidt, A., Hoist, A., & Machur, W. (2022). Driving Ambitions: The Business Case for Circular Economy in the Car Industry. World Economic Forum. p 4

[279]Where do shared autonomous vehicles go next? (2023). McKinsey & Company.

[280]The road to affordable autonomous mobility. (2022). McKinsey & Company.

[281]See for example 'Robotaxis will be disruptive to conventional taxis and ridehailing, but not car ownership', says new report. (2021, November 2). Robotics & Automation News. and McCandless, J. (2021, November 5). Robotaxis May Be the Transportation Industry's Next Major Disruptor. Newsweek.

Hyundai_Ioniq_5_Robotaxi

Research has also found near term potential for on-demand private or pooled robotaxi services to be profitable to operators and affordable for consumers in non-urban regional areas, where a median profitability margin of around three percent may be possible.[282] However, a regional market has fewer overall customers than a dense urban environment, making the near-term business opportunity and investment case appear less compelling to investors. The present-day costs of operating shared passenger AV services in a major metropolitan city could be between $30 and $60 per mile, depending on the size of the fleet.[283] Nearer term profitability in other applications, such as middle-mile delivery, appears more tangible.[284]

The development of advanced driver assistance and autonomous vehicle technologies is a cash-intensive high-tech research endeavor that requires significant injections of on-going funding to survive and thrive. There remains strong near-term potential for ADAS technology and long-term potential for AV technology to transform the transportation system and strengthen the economic competitiveness of the United States and its allies. However, a bridge is needed to this future to help U.S. and allied innovators cross the "Valley of Death." Private sector investment in robotaxi and automated delivery operations is declining, dropping 60 percent in 2022 compared to the previous year.[285] Lay-offs and closures have blighted the U.S. AV sector in the past year.[286] The uncertain economics of the near-term profitability of this sector on the passenger side of AVs means that there is no strong immediate incentive for private investors to supply the necessary capital to autonomous vehicle development in the United States, unless there is a clear signal from national policymakers that advanced mobility technologies are a federal policy priority, backed up with concrete policy actions.

In the absence of major policy commitments, it is difficult for companies and major investors to see the value of investing in technologies, vehicles, and services that will take a long time to pay off, when they are beholden to quarterly earnings cycles or expectations for relatively near-term exits. China, in contrast, has used policy alongside public subsidies to create a favorable investment environment, which has stimulated the creation of hundreds of new companies.

Before the IRA and BIL, nearly half of all global automaker investment spending in electric vehicle technology was targeted at China.[287] At the end of 2020, U.S. investments were lagging both Asia and Europe, with just $51 billion in domestic EV and battery manufacturing, less than half of the $115 billion announced for China at that time and behind both Europe and the rest of Asia.[288] The IRA and BIL contained $83 billion for EV and battery production. This injection of public funding has been accompanied by $210 billion in private investments for EV and battery manufacturing.[289] Bold policy decisions

[282]Bösch, P. M., Becker, F., Becker, H., & Axhausen, K. W. (2018). Cost-based analysis of autonomous mobility services. Transport Policy, 64, 76-91.

[283]Figures based on conversion into miles and U.S. dollars of data from a 2021 report by published by Oxbotica (now Oxa), Imperial College London and Transport for London (TfL) which identified the potential impact of autonomous vehicle (AV) services deployment on major UK cities. See The SHIFT Autonomous Vehicle Deployment Report. (2021, March 15). Oxa.

[284]Ohnsman, A. (2023, September 5). Forget Robotaxis. Upstart Gatik Sees Middle-Mile Deliveries As The Path To Profitable AVs. Forbes.

[285]Hawkins, A. J. (2023, April 25). Cruise continues to burn GM's cash as robotaxis expand to daylight hours. The Verge.

[286]See for example Ford, Volkswagen-backed Argo AI to shut down. (2022, October 26). Reuters. and Hawkins, A. J. (2023, May 10). Nuro plans for more layoffs as the AV sector's economic woes deepen. The Verge.

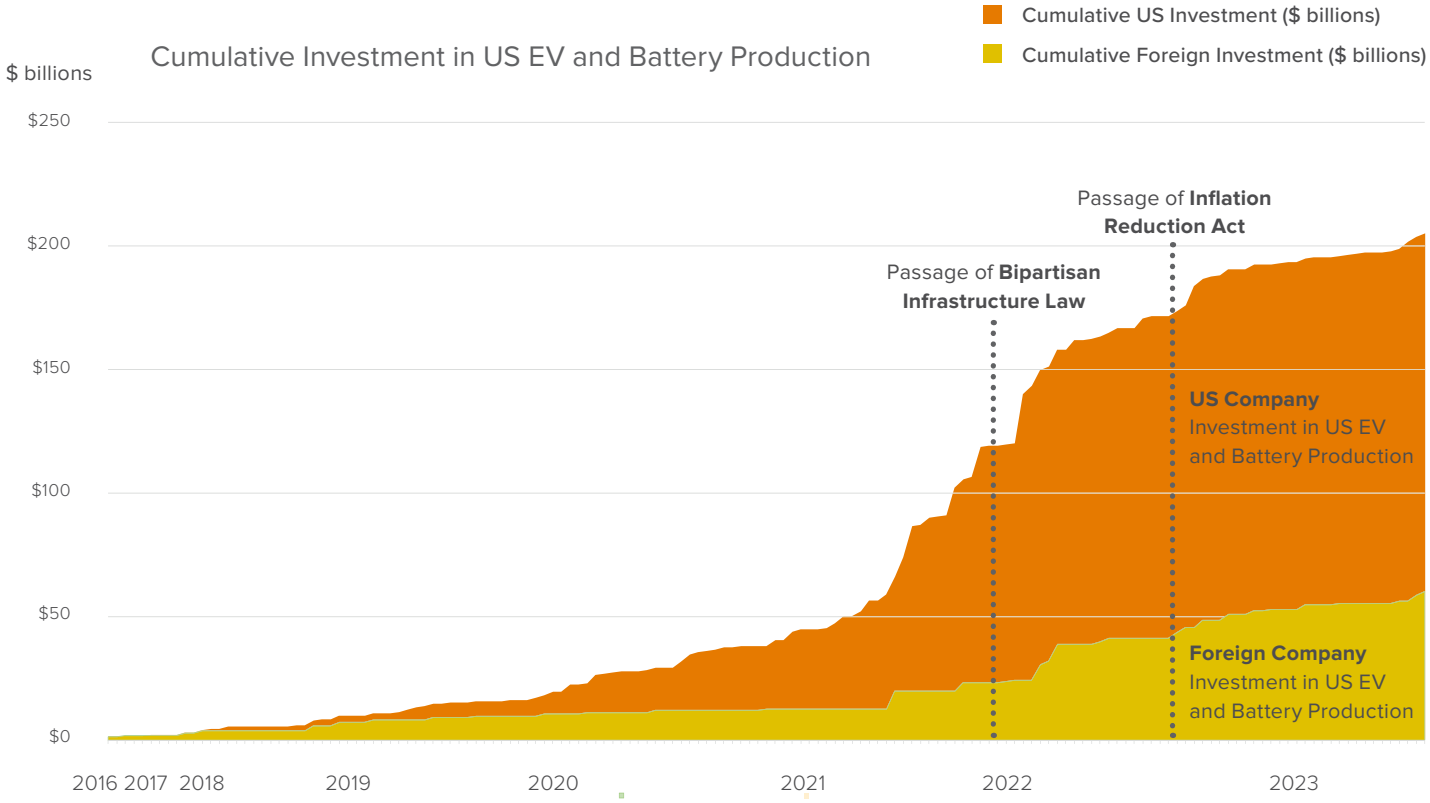
[287]Exclusive: VW, China spearhead $300 billion global drive to electrify cars. (2019, January 10). Reuters.

[288]$210 Billion of Announced Investments in Electric Vehicle Manufacturing Headed for the U.S. (2023, January 12). Atlas EV Hub.

[289]Ibid

Figure 12: Federal Subsidies Drive Private Investment

The passage of the Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law (BIL) stimulated additional private sector investment in U.S. domestic electric vehicle and battery production supply chains for a cumulative total of $200 billion in private investment. Much of this growth has been generated from U.S. companies investing in US supply chains, creating high quality jobs in strategic sectors.



Source: ReMo analysis based on Atlas EV Hub Data

by the United States to prioritize EVs and battery technology has therefore helped to bridge private sector investment uncertainty. The United States now has the chance to become a global leader in the EV transition and realize the profound economic benefits of renewed strength in automotive and transportation manufacturing.

Given the strategic national importance of connected and autonomous vehicle technology, there is also significant potential for the defense sector to partner more effectively with the commercial AV sector. U.S. defense sector investments in research and development led to transformative technologies such as GPS and the DARPA projects that are the roots of the commercial AV sector. Defense contracts for AV technology could, for example, utilize off-the-shelf technology developed by the commercial AV sector, and provide the commercial sector with a portion of the investment necessary to further develop and test AV technologies.[290]

Consumer Acceptance and Demand Challenges

Consumer confidence in autonomous vehicle technology has experienced a decline in recent years. According to a 2023 study by the American Automobile Association (AAA), 68 percent of American drivers expressed fear about fully autonomous vehicles, up from 55 percent in 2022.[291] This mirrors Pew

[290]Acox, P., & Raval, A. (2023). Missing Sybergy: How Defense, Commercial Sectors Can Benefit Each Other. National Defense.
[291]Moye, B. (2023, March 2). AAA: Fear of Self-Driving Cars on the Rise. AAA Newsroom.

AVs Reduce **Collision Risks**

AVs reduce collisions by

65%

AVs reduce property damage claims by

76%

Source: Lillo, L. D., Gode, T., Zhou, X., Atzei, M., Chen, R., & Victor, T. (n.d.). Comparative Safety Performance of Autonomous- and Human Drivers: A Real-World Case Study of the Waymo One Service.

Research which found that around 45 percent of Americans think AVs would be bad for society, and they would not be comfortable sharing the road with an AV.[292] Factors contributing to this skepticism include high-profile crashes involving autonomous vehicles, such as the fatal Uber self-driving car crash in 2018.[293] Media coverage of such incidents tends to spotlight the technology's current limitations, exacerbating public fear. Moreover, the complexity and variability of real-world driving conditions challenge the readiness of current autonomous systems. Without more transparent communication regarding its capabilities and limitations, it is likely that public trust in this transformative technology will remain limited.[294]

The primary barrier to the acceptance of AVs appears to stem from the public's limited exposure. To enhance the public's perception of AVs, it is essential to directly introduce them to the technology. Robotaxi services like Waymo and Cruise are available around the clock in a handful of markets, which will expand public exposure to AVs in those cities.[295] Indeed, a recent J.D. Power survey found that positive first-hand experiences tend to build consumer trust and overcome the fragility of consumer acceptance, with 47 percent of robotaxi riders gaining trust during a ride, and only 2 percent of riders losing trust in robotaxi capabilities during a ride experience.[296] However far more public education and public opportunities to try autonomous vehicle technologies are therefore needed. In contrast, advanced driver assistance systems that make driving safer – such as blind spot warnings, forward collision warnings, rear mirror cameras, automatic emergency braking for vulnerable road users and night vision – are gaining increased consumer acceptance.[297]

Turning to vehicle connectivity, security and safety of data underlies persistent consumer hesitancy about this technology. Specifically, market research has found that 63 percent of U.S. consumers have privacy concerns about connected cars, while 54 percent fear the threat of a cyber-attack.[298] Consumer resistance is generational in nature – Boomers and Gen Xers have far less interest in connected cars than Millennials, for example.[299] Access to and security of consumer vehicle data is an unresolved problem on the policymaker side, and is the subject of ongoing legislative attention in California[300] and in the European Union.[301]

Electric vehicle technology also faces ongoing consumer acceptance challenges. As noted already in this report, the up-front sticker price of most electric vehicle models in the United States and Europe remains persistently high. A 2023 poll by the Associated Press-NORC Center for Public Affairs Research and the Energy Policy Institute at the University of Chicago found that electric vehicles remain prohibitively expensive for most Americans.[302] Six in 10 respondents to that survey said that the high upfront cost of EVs are

[292]Nadeem, R. (2022, March 17). 4. Americans cautious about the deployment of driverless cars. Pew Research Center: Internet, Science & Tech

[293]'Inadequate Safety Culture' Contributed to Uber Automated Test Vehicle Crash—NTSB Calls for Federal Review Process for Automated Vehicle Testing on Public Roads. (2019, November 19). National Transportation Safety Board.

[294]Penmetsa, P., Adanu, E. K., Wood, D., Wang, T., & Jones, S. L. (2019). Perceptions and expectations of autonomous vehicles – A snapshot of vulnerable road user opinion. Technological Forecasting and Social Change, 143, 9–13.

[295]See Mickle, T., Lu, Y., & Isaac, M. (2023, August 21). What Driverless Waymo Taxi Rides Are Like in San Francisco. The New York Times. and Korosec, K. (2023, May 4). Waymo doubles robotaxi service area in Phoenix in bid to grow driverless trips tenfold. TechCrunch.

[296]2023 U.S. Robotaxi Experience Study. (2023, October 19). J.D. Power.

[297]Consumers desire automated safety over self-driving tech. (2023, June 13). IHS Markit.

[298]Consumer interest in 'Connected Cars' is rising slowly but ongoing concern over privacy and the threat of cyber-attacks hamper greater demand. (2021, September 1). Harris Poll. theharrispoll.com/briefs/connected-cars/

[299]Ibid

[300]State of California. (2023, July 31). CPPA to Review Privacy Practices of Connected Vehicles and Related Technologies.

[301]Foo, Y.C. (2023, April 23). EU car data access rules in progress but no timeline. Reuters.

[302]New Poll: 2 In 5 Would Consider Purchasing An Electric Vehicle As Their Next Car, But They Remain Prohibitively Expensive For Americans. (2023, April 10). Energy Policy Institute at the University of Chicago.

a major reason they would not buy one, matching similar survey findings that found high prices and a lack of charging infrastructure dissuaded at least half of both Democrats and Republicans from wanting to buy an EV.[303]

Liability and Insurance Challenges

Typically, in the United States (and other countries), if a person is injured in an automobile crash, then the person who is at fault for the crash (or their insurer) is legally liable and must pay damages to the injured person. This approach to liability is not suited to autonomous vehicles, because it can be extremely difficult to determine how an AI application or algorithm came to a decision – this is called the Black Box Effect.

Under the
Current System

98%

of automobile crashes in the United States are caused by human error.

25-40%

of the compensation an auto crash victim receives is taken by their attorney in fees

Source: U.S. General Services Administration Office of Motor Vehicle Management; Forbes Advisor

A crash involving an autonomous vehicle under a fault-based system will require a highly technical, lengthy, and expensive legal and insurance process to identify whether the automated driver assistance system/autonomous vehicle was the cause of the crash. Under a fault-based system it is also uncertain who should be liable for an AV-linked crash – the OEM manufacturer, the driver/operator, third party software companies, or another component manufacturer. This system imposes complexity, cost and uncertainty for autonomous vehicle manufacturers and service operators.

A major barrier to the deployment of autonomous vehicles and services is uncertainty about legal liability in the case of crashes involving AVs or the ability of manufacturers and AV companies to secure adequate insurance coverage.[304] This is a man-made legal policy failure with significant consequences, given that 98 percent of automobile crashes in the United States are caused by human error.[305] Others have highlighted in the past that that a no-fault approach for AVs may help manufacturers avoid liability costs that slow innovation[306] – but this important reform has been held back because of political challenges. Any efforts at reform would face stiff opposition from the legal profession, which benefits financially from the status quo – between 25 to 40 percent of the compensation an auto crash victim receives is taken by their attorney in fees.[307]

Reform of U.S. automobile liability law in line with international best practice could deliver insurance cost savings for consumers and better access to justice. However, all federal reform efforts have been persistently stymied over decades by the U.S. trial lawyer lobby.[308]

Beyond the liability challenges specific to AVs, the insurance industry has consistently needed to reestablish and rethink its models as new mobility innovations have come to market. This was the case with TNCs, when ridehailing drivers regularly operated commercially using personal insurance policies. A similar dynamic has been the case with car sharing and micromobility offerings, where the ability for disruptive

[303]Many Americans aren't yet sold on going electric for their next car, poll shows. (2023, April 11). PBS NewsHour.

[304]Autonomous Vehicles: Change is Coming. (2022). Marsh. p 15

[305]Crashes Are No Accident. (n.d.). U.S. General Services Administration Office of Motor Vehicle Management.

[306]Anderson, J. M., Kalra, N., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, T. A. (2016). Autonomous Vehicle Technology: A Guide for Policymakers. RAND Corporation.

[307]Car Accident Lawyer Fees 2023 Guide. (n.d.). Forbes Advisor.

[308]Kinzler, P. (2021). Highway Robbery: The Two-Decade Battle to Reform America's Automobile Insurance System. University Press of Kansas.

new technology to scale was ultimately limited by questions of how to use these new services.

Reform of insurance and liability approaches to all new mobility technologies is urgently needed in general. The concept of a vehicle is changing radically through new technology – and insurance companies have to factor in how this impacts their products and pricing.[309] The different driving experience, increased acceleration and instant torque has shown that EVs can be involved in up to 50 percent more collisions than ICE vehicles. Additionally, manufacturer specific parts and limited aftermarket options mean the average claim for an EV consistently exceeds that of an ICE vehicle.[310] Meanwhile, uncertain liability and high insurance requirements have threatened to put shared micromobility services out of business in some locations,[311] even though e-scooter and e-bike injuries and fatalities have in general continued to decrease in many markets.[312]

Industrial and Workforce Challenges

All the national security, economic and human benefits of a reimagined mobility system can only be leveraged if a coordinated policy approach to novel, society-changing technologies is taken at the national, state, and local levels in the United States and by its allies. This approach is needed because the challenges of workforce resistance to connected and autonomous vehicle technologies, and a lack of sufficient private sector investment into these sectors, will not be resolved without coordinated policymaker effort.

Investing in the future means championing manufacturers and innovators across a diverse range of sectors, beyond the industries and actors that currently benefit from the IRA and BIL. Investing in new mobility infrastructure means transportation, communication, and information infrastructure (including digital infrastructure) should be planned, designed, and operated as an integrated system, not as individual silos managed by different government departments and agencies.

A whole-of-government policy approach is needed because many of the policy levers, skills training and wider policy landscape that are necessary to support a reimagined mobility system require strategic and coordinated long-term industrial policy choices. These policy choices should be made at the national level, to ensure that all relevant macroeconomic, societal, and national security considerations can inform the development of policies specific to particular sectors and technologies.

Investing in the future means championing manufacturers and innovators across a diverse range of sectors, *beyond the industries and actors that currently benefit from the IRA and BIL.*

The U.S. federal government has already indicated its willingness to engage with stakeholders and work cross-divisionally to address regulatory barriers to deployment, for example in the area of vehicle connectivity. In 2023 a significant development was achieved when three Federal Communications Commission (FCC or Commission) bureaus – the Public Safety and Homeland Security Bureau, the Office of Engineering and Technology, and the Wireless Telecommunications Bureau – granted a joint request submitted by automotive manufacturers, equipment manufacturers, and state departments of transportation seeking a nationwide waiver of several FCC rules to permit deployment of C-V2X technology.[313] More of these kinds of bold policy actions are required to accelerate the life saving and freedom-enhancing potential of connectivity and other mature transportation mobility technologies.

In a recent development, the Biden administration released its Unified Regulatory Agenda in June 2023, which featured a NPRM by NHTSA, termed the Exemption and Demonstration Framework for Automated Driving Systems. As previously noted, this proposal seeks to outline a method for NHTSA to evaluate specific aspects of automated driving systems and AVs, including considerations like exemptions, protocols for crash avoidance tests, and the integration of these systems into commercial vehicles. Nonetheless, it is important to note

[309]Can European insurtechs live up to the hype? (2023, August 30). McKinsey & Company.

[310]See for example Corporate, C. C. C. (2023, July 11). Will Electric Vehicle Regulations Continue to Force Change? CCC Intelligent Solutions. and Claims data points to high-end electric car risks: AXA. (2019, August 22). Reuters.

[311]Islas, J. (2022, October 26). Did California Just Kill Shared Micromobility? Streetsblog California.

[312]Injury rates on shared e-scooters fall by 19% in 2022, according to new data from Micro-Mobility for Europe. (2023, June 5). Micro-Mobility for Europe.

[313]FCC Approves C-V2X Technology for Connected Vehicles Ahead of Final ITS Rules. (n.d.). JD Supra.

that these initiatives do not signify a complete overhaul of the existing federal laws and regulations.

The Digital Industrial Revolution, workforce resistance and the power of the market economy

The technologies that underpin both advanced transportation technologies and advanced communications technologies form part of a broader evolution in human and economic development that can be classified as a Digital Industrial Revolution (DIR).

DIR is the next phase in the digitization of the manufacturing sector, driven by disruptive trends including the rise of data and digital connectivity and human-machine interaction. In the past, the concept of this transformation was given names such as the Fourth Industrial Revolution.[314] However this transformation is already underway and builds on previous technological and business evolutions which delivered widespread freedom in the 20th century through automobiles and computer technologies.[315] The main potential benefits of DIR are lower barriers between inventors and markets, a more active role for artificial intelligence (AI), convergence of different technologies, improved quality of life through robotics, and enhanced internet connectivity.[316]

Yet one of the main challenges of DIR is its potential to massively disrupt and displace jobs that are currently performed by humans. Nowhere is this potential disruption more obvious than in transportation, where connected and autonomous vehicle technology stands to transform, or even in some cases, eliminate the tasks of a human driver. The positive, whole-of-society benefits of this fundamental shift in how we live will not be realized if the human disruptions of this transformation are not thoughtfully considered and prepared for, with direct consideration of the human role in and impact of this transition.

Human workers feel threatened by DIR (and in particular AI technologies) due to concerns about job displacement and devaluation of human skills. As automation, machine learning, and AI technologies continue to evolve, they can perform a broad array of tasks traditionally completed by human workers. This ranges from manual labor to more complex cognitive tasks. These broad advancements raise fears and feed narratives of job loss, as roles once filled by humans might become automated. Moreover, the rapid pace of technological change can lead to a skills gap, where the knowledge and abilities of the workforce do not align with the demands of newly created or transformed roles in the same sectors.

For example, it may not be immediately obvious to a truck driver how their skills can be translated into a new role where automation replaces the core driving task they currently perform, even though there are quality assurance, human interaction, or supervisory roles that would require truckers' unique skills.[317] There is a perception that these technologies will devalue the skills of existing workers, creating additional economic insecurity and threatening workers' sense of value and purpose in their work.

Truck Driver **Shortage**

Today's United States truck driver shortage of more than

80,000

drivers is set to grow to a shortage of

160,000

drivers by 2030.

Source: American Trucking Association

[314]What is industry 4.0 and the Fourth Industrial Revolution? (2022, August 17). McKinsey & Company.

[315]Xu, M., David, J. M., & Kim, S. H. (2018). The fourth industrial revolution: Opportunities and challenges. International journal of financial research, 9(2), 90-95

[316]Ibid.

[317]Gittleman, M., & Monaco, K. (2019, September 18). Automation Isn't About to Make Truckers Obsolete. Harvard Business Review.

We already see the political pressure of this resistance manifesting itself in reactionary legislative measures, such as a California bill that would have required a trained human safety operator to be present any time a heavy-duty autonomous vehicle operates on public roads[318] – ostensibly in the name of public safety but also to protect the job security of human truck drivers. If passed, this bill would severely limit the ability of the California Department of Motor Vehicles to test and deploy autonomous trucks without seeking approval from the state legislature. However, building political and regulatory barriers to autonomous vehicle technology deployment in the freight sector risks worsening the existing human labor shortage in this sector. Today's United States truck driver shortage of more than 80,000 drivers is set to grow to a shortage of 160,000 drivers by 2030.[319] To address this gap, the trucking industry would have to recruit over a million new drivers into the industry by 2030, to account for retirements, attrition, and freight sector growth.[320] This is likely to be difficult for the industry to achieve, due to stringent driver qualification requirements for inter-state haulage and challenging work conditions for drivers.[321]

These kinds of very real workforce challenges – and the associated highly-charged political debates – can only be resolved through an all-of-government policy coordination on the strategic impacts of technological change, which aims to support working people's economic opportunities while leveraging the immense macro-level economic and productivity benefits of advanced mobility and communication technologies.

Areas Where New Policy Solutions are Needed

As the United States stands on the precipice of a digital industrial revolution, the nation's mobility landscape is poised for unprecedented transformation. Emerging technologies, evolving consumer behaviors, and twin imperatives for sustainability and renewed industrial strength are shaping the future of how Americans move.

Yet, to truly harness the potential of this new mobility era, policy frameworks that are ambitious, flexible, and comprehensive must be facilitated. From understanding the profound impacts of the Digital Industrial Revolution on our industrial fabric to recognizing and addressing the regulatory challenges of innovative vehicle designs, the journey to reimagine mobility is as complex as it is exciting.

This section identifies pivotal areas where ambitious policy interventions are crucial: the need for an all-of-government approach on digital industrial policy, regulatory considerations for new vehicle form factors, the intricacies of transportation funding and planning, the evolving landscape of liability and insurance, and the pivotal role of efficiency and circularity in shaping the future of mobility.

The challenges associated with new policy in these areas are multifaceted and complex, and interwoven with different technology and manufacturing sectors, stakeholders, and socio-economic factors. It would be an overreach to present this report as a panacea offering complete solutions

[318]The bill was eventually vetoed by the California governor. See Bill Text—AB-316 Vehicles: Autonomous vehicles.

[319]Driver Shortage Update 2021. (2021). American Trucking Associations, Inc.

[320]Ibid.

[321]ATA Statement on Flaws in Bureau of Labor Statistics' Driver Shortage Article. (2019, March 19). American Trucking Associations.

– therefore ReMo's aim is more nuanced. This report provides a roadmap at this critical juncture, identifying pivotal starting points for convening private and public stakeholders together and emphasizing areas that require immediate policymaker attention, to reimagine mobility for the benefit of people, the economy and overall prosperity. Spotlighting these priority areas aims to jumpstart constructive discourse, inspire further research, and guide strategic decision-making. Recognizing the initial steps is a crucial step of the journey towards meaningful solutions in the pursuit of a reimagined mobility future.

All-of-government policy on the strategic impacts of technological change

An all-of-government federal policy direction on the DIR, leveraging reimagined mobility and digital communications technology advancements does not mean emulating China's authoritarian, government-controlled socialist market economic model. Rather, a democratic capitalist and market-led approach to enabling freedom through reimagined mobility and digital communications technology is required – one that is unequivocally supported by federal policies that impact underlying system dynamics and technology innovation opportunities.

Market capitalism is core to U.S. economic strength – 9 out of 10 of the world's largest public companies are U.S. corporations.[322] Market capitalism, where the private sector owns and controls the means of production, was central to the birth and growth of the U.S. automotive industry throughout the 20th century. That industry served as the foundation of the U.S. industrial base, generating substantial economic benefits that have fostered a vibrant U.S.-based technology ecosystem.[323]

However, this impressive market-based growth did not occur in a policy vacuum. The growth of the private sector-led automotive industry was directly and positively impacted – but not controlled – by the system dynamics and feedback loops favoring the automobile that flowed from supportive U.S. federal policies such as the development of the Interstate Highway System via the Federal Highway Act of 1956. Similarly, the Inflation Reduction Act has created supportive feedback loops in energy policy, particularly transportation, which will create an estimated $2.9 trillion of cumulative investment opportunity by 2032.[324]

Meanwhile, the growth of Silicon Valley ingenuity and the blossoming of the U.S. digital technology sector was facilitated by the convergence of reliable and significant U.S. government defense funding, a large pool of skilled engineers and scientists from around the world studying at local universities, academic leadership, and a network of venture capital firms.[325]

The United States could take inspiration from successful initiatives in South Korea to prepare for DIR. In 2016, Korea's Ministry of Science and Information and Communication Technology and Future Planning (now the Ministry of Science and ICT) published a Mid- to Long-term Master Plan in Preparation for the Intelligent Information Society. This plan set three thematic goals: securing the foundations of world-class intelligent information technology, applying of intelligent technology to all industrial sectors, and reforming social policies to proactively respond to the challenges of the so-called Fourth Industrial Revolution.[326] Meanwhile, Korea's Presidential Committee on the Fourth Industrial Revolution (PCFIR) assembled the expertise of five ministers and more than twenty private sector stakeholders with the aim of reforming and implementing policies in fields such as science and technology, industry, infrastructure, education, and social welfare, all with a view to actively tackling the challenges presented by strategic digital technologies. Since its inception in 2017, the PCFIR has been pivotal in formulating and launching ambitious policy recommendations for governmental backing in crucial industrial sectors, reformation of laws and regulations, and fostering talent development and retention.[327]

This sort of coordinated national policy addressing the strategic impacts of technological change should be replicated

[322]Neufeld, D. (2022, December 26). Ranked: The 100 Biggest Public Companies in the World. Visual Capitalist.

[323]Hill, K., Cooper, A., and Menk, D. (2010). "Contribution of the Automotive Industry to the Economics of all Fifty States and the United States," Center for Automotive Research.

[324]The U.S. is Poised for an Energy Revolution. (2023, September 14). Goldman Sachs.

[325]Castells, M. (2010). The Rise of the Network Society. Wiley.

[326]Kim, D. (2021). South Korea as a Fourth Industrial Revolution Middle Power? Korea Economic Institute of America.

[327]Ibid. See also The Presidential Committee on the 4th Industrial Revolution. (2017). EC-OECD STIP Compass.

in other countries and markets, embracing perspectives from industry, academia, workforce, and digital technology sectors, to ensure that technological advancements benefit all, rather than exacerbate existing social and economic disparities, with thoughtful strategies focused on re-industrialization, economic development, reskilling, job transitions, and education. Future ReMo work will explore in greater details what form this sort of national policy and coordination might take, and how policies can and should be tailored to account for national systems, cultures, and policy dynamics.

Addressing regulatory barriers and gaps that throttle the transformation of our vehicle fleet

The United States vehicle regulatory landscape has key barriers and gaps that presently inhibit the seamless transformation of our fleet to a more efficient and sustainable system.

Bringing tailored vehicles to market

The U.S. and allied automotive sector currently have limited market incentive or encouragement to produce the various kinds of less expensive, right sized, and connected vehicles that will help new types of mobility options to flourish. This is because of legacy systems and attitudes to vehicles, however staying on this path risks conceding to China's growing strength in the entry-level EV and right-sized connected and autonomous vehicle segments. Staying on this path also undermines the gains the United States and its allies have recently made in vehicle electrification, and ultimately prevents effective steps to address big transportation challenges in emissions, safety, accessibility, and efficiency.

NHTSA serves a critically important role in vehicle safety through vehicle design specifications, but the law as it is written currently has likely contributed to increased cost and vehicle weight over time. From 1968 to 2012, the FMVSS vehicle safety technology has added 171 pounds and $1,929 to the average passenger vehicle.[328] Further, the cost and weight of passenger vehicles have continuously grown over the 44 years since FMVSS was established. An issue can arise if the trend continues – heavier and more expensive vehicles as a function of increased safety – vehicles deemed safest may end up being financially out of reach for many Americans. However, lightweight materials and smaller vehicles can be engineered to perform as well as existing heavier vehicles in crash situations and also contribute to less severe vehicle crashes.[329] By striking a balance between safety standards and affordability, federal agencies including NHTSA can foster innovation and encourage the automotive industry to pursue technological advancements that promote both vehicle safety and economic affordability for American consumers.

Currently, federal regulations are an obstacle to innovation for companies developing novel vehicle designs. Novel vehicle design is beholden to antiquated design standards, the FMVSS,

[328]Simons, J. F. (2017, November). Cost and weight added by the Federal Motor Vehicle Safety Standards for MY 1968-2012 passenger cars and LTVs (Report No. DOT HS 812 354). Washington, DC: National Highway Traffic Safety Administration.

[329]Peterson, G. (2018). Vehicle Lightweighting: A Review of the Safety of Reduced Weight Passenger Cars and Light Duty Trucks. Michigan Manufacturing Technology Center.

that mandate certain automotive parts that may not be needed for current and future tailored, novel designed vehicles to operate safely and effectively. For example, automated vehicle companies have developed new vehicle designs – such as the Nuro R2 for delivery or Cruise Origin for passengers. To date, the FMVSS requires that vehicles have windshield wipers, review mirrors, a steering wheel, etc., as these items support human operated vehicles. Novel vehicle designs by AV companies do not require these items to operate but without these features present novel vehicle designs are non-compliant and therefore prohibited from operating on the roads.

Indeed, there is a work around to the current FMVSS, Part 555 exemption, however the exemption process is inadequate. Part 555 exemptions allow certain manufacturers to test and deploy vehicles without meeting certain FMVSS for the purpose of advancing innovative technologies and promoting research and development in the automotive industry. This first challenge with Part 555 is the restrictive manufacturing condition: only 2,500 vehicles per year for two years can be manufactured under the exemption. Second, if the exemption is approved, vehicle manufacturing is only permitted for two years. The timeframe and a vehicle cap do not provide sufficient time or scale to determine viability from an economic or policymaking perspective. For context, if all 24 AV manufacturers in the United States were granted exemptions over the next 10 years less than one percent of the private and commercial fleet would be automated.[330] Limitations for novel vehicle designs impede social, economic, and environmental benefits to the system, which can only materialize with scaled deployment.

A decline in domestic automakers' competitiveness could have a ripple effect on the entire manufacturing sector, ***leading to potential job losses and economic slowdown.***

Diversifying vehicle size and design is not only crucial for the U.S. automotive industry's competitiveness but also for the overall sustainability and resilience of the nation's transportation system. Embracing a range of vehicle options that may take on new vehicle designs can be better tailored to consumer needs and preferences. Such diversification is pivotal to encouraging widespread adoption of innovative technologies across consumers of varying income levels and demographic backgrounds.

Investing in a diverse advanced vehicle technology market can also lead to significant economic opportunities. By fostering innovation and supporting domestic automakers, the United States can cement its status as a hub for cutting-edge mobility technologies, attracting talent and capital from around the world. This not only bolsters the manufacturing sector but also stimulates job growth in research, development, and support services related to new technology.

Furthermore, adopting a comprehensive regulatory framework that incentivizes innovative vehicle size and design will encourage and potentially spur more private sector investment in emerging transportation technologies. Creating a regulatory environment that encourages innovation while ensuring safety will create a path for the deployment of these vehicles.

Embracing novel vehicle size and design is not just a desirable option but an imperative one for the United States to maintain its economic productivity and secure its global leadership in the evolving transportation landscape. By fostering a robust market for different vehicle form factors, the United States can drive sustainable growth, enhance environmental sustainability, and position itself as a trailblazer in the future of mobility. Without the right policies, investments, and a collaborative effort between government and private industry, the nation will have to deal with a bevy of consequences at the national and global level.

Unfortunately, the risk extends to the broader economy. The automotive industry is not just a key contributor to the nation's GDP, but it also has a vast network of suppliers and downstream industries that rely on its success. A decline in domestic automakers' competitiveness could have a ripple effect on the entire manufacturing sector, leading to potential job losses and economic slowdown.

[330]SAFE analysis.

Addressing these risks requires a strategic approach that focuses on fostering innovation, supporting research and development, and incentivizing domestic automakers to invest in diverse vehicle technologies. Policymakers must collaborate with industry stakeholders to develop comprehensive strategies that encourage the adoption of new technology while supporting domestic manufacturers in their transition towards a more sustainable and diverse product lineup. By taking proactive measures to enhance the competitiveness of American automakers, the United States can secure its position as a central player in the global advanced technology market and ensure economic prosperity and leadership in the transportation industry for years to come.

Fuel economy and greenhouse gas emission standards

Although most auto manufacturers have improved CO_2 emissions and fuel economy in light-duty passenger vehicles and light trucks over the past five years, horsepower, weight, and footprint are all at record highs. In its 2022 Automotive Trends Report, the EPA reported that while fuel economy has increased in all vehicle types since model year 2008, the market shift overall towards less efficient vehicle types has offset some of the fleetwide fuel economy and CO_2 emission benefits that otherwise would have been achieved.[331]

Current fuel economy regulations are harmonized under the National Program,[332] which runs until 2026. The EPA recently published its proposed pollution standards that would apply from market year 2027,[333] and NHTSA is expected to soon publish a proposal for the next phase of its fuel economy standards. The National Program is jointly administered by two federal agencies, and they operate with different authorities and mandates – NHTSA is charged with improving vehicle efficiency in pursuit of reduced oil consumption, while the EPA regulates tailpipe emissions of greenhouse gas emissions (GHGs) in pursuit of U.S. climate policy goals. As such, there are notable inconsistencies within the National Program that create inefficiency as new technologies emerge, as well as complex regulatory burdens for manufacturers.

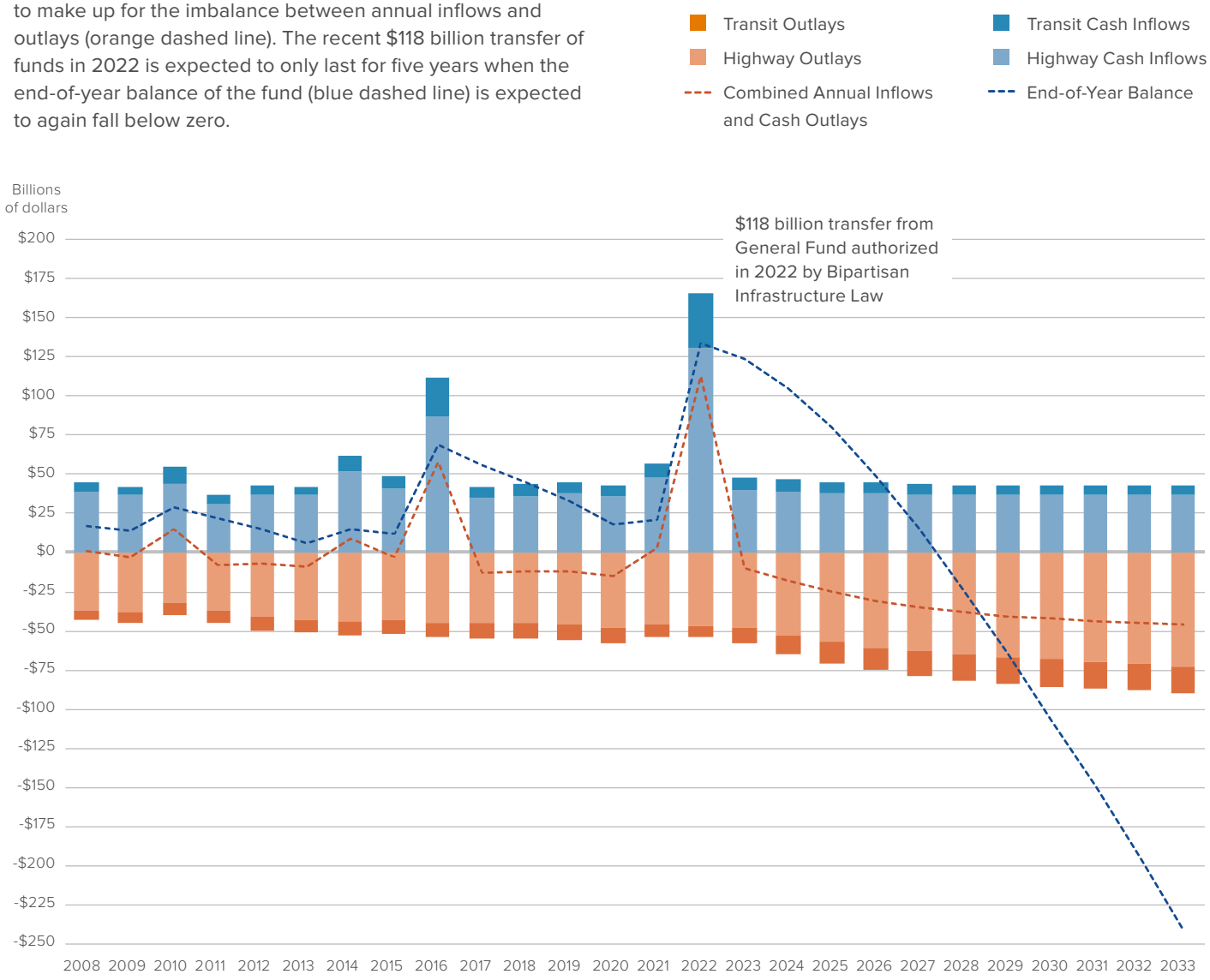
[331]The 2022 EPA Automotive Trends Report. (n.d.). U.S. Environmental Protection Agency p 32

[332]U.S. Department of Transportation & U.S. Environmental Protection Agency. (2019). One National Program Rule on Federal Preemption of State Fuel Economy Standards.

[333]U.S. Environmental Protection Agency. (2023, April 12). Biden-Harris Administration Proposes Strongest-Ever Pollution Standards for Cars and Trucks to Accelerate Transition to a Clean-Transportation Future

Figure 13: Highway Trust Fund.

The Highway Trust Fund is dependent on injections of capital to make up for the imbalance between annual inflows and outlays (orange dashed line). The recent $118 billion transfer of funds in 2022 is expected to only last for five years when the end-of-year balance of the fund (blue dashed line) is expected to again fall below zero.



Source: ReMo analysis based on May 2023 data and projections from Congressional Budget Office

First, the current National Program features two regulators with two very different policy objectives and areas of expertise. Additionally, the production of two sets of standards – one for fuel economy and the other for emissions – doubles the complexity and burden for manufacturers. In essence, both frameworks concern energy, the efficiency of its use, and the impact of excessive fuel use – but from very different perspectives.

Second, separate fuel economy standards for cars and light-duty trucks means that larger vehicles are subject to less stringent fuel economy standards. This dynamic emerged from the first attempts in the 1960s and 70s to regulate emissions in a way that did not unfairly penalize utilitarian trucks used for infrastructure maintenance, farm use, towing, and by tradesmen. The regulators who devised them likely did not contemplate the emergence of minivans, SUVs, and extended cab pickup trucks – all of which are predominately used in the same way as a regular passenger car. These large vehicles have very poor energy efficiency and fuel economy regardless of whether they feature an electric or internal combustion motor. Simply put, a bigger vehicle uses more energy to move and materials to build, regardless of its source. An oversized

vehicle fleet also leads to much worse safety outcomes for other road users, particularly vulnerable pedestrians like children. Electric versions of large vehicles also require increased quantities of expensive, critical minerals and make the sticker price of electric vehicles persistently higher than their internal combustion counterparts.

However, changing the status quo is difficult because these vehicles have proven extremely popular with American consumers over decades, who relish the freedom, space and power offered by large vehicles. The only way forward lies in recognizing that the current national system needs reform, while simultaneously respecting consumers' right to choose the kind of vehicle that suits their lifestyle. A new framework must enhance efficiency as well as the variety of vehicles available in the market beyond existing vehicle classes of compact cars, sedans, SUVs and pickup trucks.[334]

The National Program is a cornerstone of U.S. energy policy, but current fuel economy standards were designed specifically around oil dependence and are ill-suited to the challenges of today, and an electrified transportation future that is also connected and autonomous. The program should not be expected to contemplate the current supply chain crisis for the minerals necessary for batteries, the growth of China as America's key economic rival, vehicle affordability issues, new autonomous and driver assist technology, worsening road safety outcomes, or climate change. OEMs increasingly function as mobility and technology companies that move both people and goods. It is widely expected that the current incentives and consumer demand for electrification will lead to a large market share of battery electric vehicles by the early 2030s. It is therefore critical now, in the mid-2020s, to begin the process of imagining a new regulatory framework that would apply from the early 2030s (after the expiration of the next phase of the National Program). A new regime could remove existing inconsistencies in the regulatory framework, designate one regulator, and set clear standards for fuel economy and efficiency of EVs as well as internal combustion vehicles. This would give certainty to manufacturers and consumers about what the future of fuel economy and efficiency standards will be for what is projected to be a predominantly battery electric fleet.

An opportunity therefore presents itself now to reconceptualize fuel economy and greenhouse gas regulatory benchmarks in the context of an autonomous, connected, and electric vehicle era. This new framework could be tailored for heightened efficiency as well as maintaining freedom of choice, and would optimize the utilization of clean energy, minerals, and materials for superior efficiency.

U.S. transportation funding & planning systems are not designed for the future

The way that mobility and connectivity of people and goods is funded, planned, and regulated in the United States is also designed for a 20th century transportation system. Funding and planning approaches for mobility have not adapted to the way that information and mobility technology have begun to converge to enable freedom. Radically changing these funding and planning structures will help to accelerate mobility innovations that have the most beneficial social and economic impact.

Federal policies that control roadway infrastructure and investment have resulted in an automobile dependent transportation system in most of the United States. Since the 1980s, federal infrastructure spending has primarily been invested in bridges and roads. Eighty percent of federal transportation infrastructure funding goes to highway and road building and maintenance, while the remaining 20 percent is spent on mass transit.[335] The large investment in roads leaves a massive gap in funding for other modes like public transit, new forms of small battery powered micromobility from electric bikes to scooters, walking, or biking, contributing to it being a less attractive option compared to traveling via private vehicle for many Americans. This disparity contributes to the widespread car dependency seen in the United States, reinforcing the notion that driving is often the most convenient and accessible mode of transportation for many Americans. Although highways and roads receive the lion's share of investment, staying up to date with road maintenance has proven challenging; 43 percent of the U.S. transportation infrastructure, mostly roads, are in poor or mediocre condition.[336]

[334]Alternative Fuels Data Center: Vehicle Search. (n.d.). U.S. Department of Energy. afdc.energy.gov/vehicles/search/

[335]How We Pay for Transportation: The Life and Death of the Highway Trust Fund. (2015). Eno Center for Transportation, p 14. See also Varn, J. (2019). The Highway Trust Fund Has a Numbers Problem. Bipartisan Policy Center.

[336]Roads. (2017, January 17). ASCE's 2021 Infrastructure Report Card.

Meanwhile, transportation infrastructure funding comes from an antiquated policy. The Highway Trust Fund has financed most federal government spending on highways and mass transit since 1956. Revenues for the fund come from transportation-related excise taxes, in particular federal taxes on the sale of gasoline and diesel fuel. However, this source of revenue has become insufficient to even maintain the current system. The gas tax is currently 18.4 cents per gallon and has not changed since 1993, leading to declining real revenue due to inflation, improved fuel efficiency of vehicles, and the proliferation of electric vehicles. Consequently, there is an increasing funding gap for maintaining and upgrading the nation's roads, bridges, and transit systems, hindering economic growth, and jeopardizing the safety of commuters. The Highway Trust Fund has been effectively insolvent for over a decade and has required regular injections of general taxpayer funds to stay solvent. The Congressional Budget Office projects that by 2031, outlays from the Highway Trust Fund will exceed trust fund reserves by close to $150 billion for the highway account and by over $50 billion for the mass transit account.[337] As vehicles become more fuel efficient or electrified this financial insolvency is expected to become more pronounced.

In terms of digital infrastructure funding, apart from the packages for EV Charging Networks and Alternative Fuel Corridors under the BIL, and other programs such as the Strengthening Mobility and Revolutionizing Transportation (SMART) grant program, current federal policy does not prioritize long-term investments in either state of good repair or new technologies. Radically changing these funding and planning structures would provide more flexibility to states and localities, help to accelerate mobility innovations that have the most beneficial social and economic impact, as well as ensuring that all parts of the transportation system pay and receive their fair share of public funding.

Most of the road, highway, and bridge infrastructure in the United States is at or past its theoretical design life. Infrastructure will need to be repaired or overhauled to fully support all applications of new mobility technologies and innovations. The types of infrastructure needed include advanced wireless communications installations and associated software, sensors, advanced road markings, smart signage, as well as more basic requirements such as well-maintained roads and appropriate infrastructure to support and promote shared and different-sized vehicles.

The United States Department of Transportation (U.S. DOT) does not typically make any direct transportation investments. Part of what U.S. DOT oversees is grant-making, and Congress has kept the conditions of those grants flexible for states. This means that when new innovations arise, states are unlikely to change their existing investment strategies absent a related change in federal policy or incentives.

To overcome these challenges, the U.S. DOT must therefore explore federal policy solutions that that remove barriers at the federal level and provide incentives at the state and local level for infrastructure investments and regulatory approaches necessary for a reimagined mobility future that addresses the big challenges ahead. Federal policy solutions could provide a more efficient source for the scale of funding investment needed to accelerate the necessary infrastructure development and mobility technologies, as well as stimulating regulatory approaches that are more supportive of innovation. In future work, ReMo intends to explore imaginative new approaches to financing and investment of the transportation system, which would support dynamic and flexible new planning approaches.

Optimizing liability and regulatory systems for a blended human & artificial intelligence future

Existing liability and risk management approaches are currently designed for mobility and connectivity that centers on human actors. This is a challenge given that we are facing a future where humans and autonomous devices will interact together. Reimagining these approaches will help to accelerate innovation and guarantee public safety.

Tort or liability law is generally a matter left to states, but Congress has precedent for enacting federal legislation that shields certain scientifically innovative and socially beneficial fields from tort liability and provided an alternative means of compensation for victims. For example, the National Vaccine Injury Compensation Program (VICP) was established in 1986 after lawsuits against vaccine manufacturers and healthcare providers threatened to cause vaccine shortages and reduce vaccination rates and herd immunity in the United States. The learnings and insights about risks and injuries achieved by the VICP over decades has informed multiple successful innovations to improve vaccine safety overall, to a greater extent than could ever have been achieved through product liability

[337]Testimony on Addressing the Long-Term Solvency of the Highway Trust Fund. (2021, April 14). Congressional Budget Office.

law. This has all to be done at a marginal cost to manufacturers and consumers – the whole scheme is funded by a 75-cent excise tax on each childhood vaccine dose administered in the United States.[338]

Similarly, during the height of the COVID-19 pandemic, the federal government gave liability exceptions to pharmaceutical companies developing new vaccines such as Pfizer, Moderna, and Johnson & Johnson. This was necessary due to the novelty of the COVID-19 vaccine and the context of the pandemic, which meant that it would have been difficult or impossible for manufacturers to secure liability insurance. This protection was issued under the Public Readiness and Emergency Preparedness Act, which empowers the Health and Human Services Secretary to provide legal protection to companies making or distributing critical medical supplies, such as vaccines and treatments.[339] The protection does not apply if there is "willful misconduct" by the company. Other healthcare actors also enjoyed this liability protection, such as healthcare professionals administering COVID-19 vaccines.[340] This approach of shared accountability supporting innovation prowess enabled U.S. pharmaceutical companies to become world leaders in COVID-19 vaccine development.

Another example comes from the aftermath of the September 11th terrorist attacks. In late 2021, Congress enacted the Air Transportation Safety and System Stabilization Act, which provided a system for streamlined compensation to victims in exchange for waiving a right to file a lawsuit against airlines. One of the specific purposes of this policy was to protect U.S airlines from financial losses and prevent them from going bankrupt, in the midst of a financial and public safety perception crisis for the aviation sector – a situation that is not dissimilar to the existential threats currently faced by connected and autonomous vehicle manufacturers and operators.

A reimagined approach to liability and insurance could help to put a culture of safety and crash prevention at the heart of AV deployment – similar to the positive "just culture" in the civil and military aviation systems. Just culture refers to a systems approach that centers on identifying "what went wrong?", rather than, "who caused the problem?" after an incident.[341] If AV manufacturers and service operators did not fear costly liability consequences of honest or unexplained errors – an expected part of the scientific innovation process – then they are more likely to share information with regulators and public officials that will help improve AVs safety and the way they are regulated. For example, a well-designed no-fault or no blame system is the internationally proven way to prioritize safety and innovation, improve crash outcomes and enhance access to justice, in multiple areas of social risk. Examples of successful no-fault or no-blame systems for transportation can be found throughout the world – including Canada, Australia, New Zealand, Israel and the Nordic countries. Across the U.S. border, no-fault has been used successfully for decades in the Canadian provinces of Quebec, Manitoba, and Ontario

[338]About the National Vaccine Injury Compensation Program. (n.d.). Health Resources & Services Administration. www.hrsa.gov/vaccine-compensation/about

[339]Declaration Under the Public Readiness and Emergency Preparedness Act for Medical Countermeasures Against COVID–19, (2020).

[340]PREP Act Immunity from Liability for COVID-19 Vaccinators. (n.d.). U.S. Department of Health and Human Services.

[341]See, e.g., Maurizio Catino, A Review of Literature: Individual Blame vs. Organizational Function Logics in Accident Analysis, Journal of Contingencies and Crisis Management, 2008.

– and the success of these systems inspired reform efforts to introduce no-fault in British Columbia and Alberta.

The concept of no-fault is not new to the United States. There are currently 12 U.S. no-fault automobile insurance states – Florida, Hawaii, Kansas, Kentucky, Massachusetts, Michigan, Minnesota, New Jersey, New York, North Dakota, Pennsylvania, and Utah. More U.S. states had no-fault systems in the 20th century, but these were scrapped – partly because the ineffective way that the systems were designed (particularly poor interaction between the healthcare insurance system and the auto insurance system)[342] as well as the failure to push lawyers and costly disputes more effectively out of the system. In 2018, the U.S. Chamber of Commerce's Institute for Legal Reform said that there was merit to the concept of federal pre-emption of state tort claims in conjunction with a federal no-fault regulatory regime.[343]However, the opportunities offered by autonomous vehicles to reduce the social risk of crashes overall present a new, compelling chance to apply this concept for the benefit of the economy and society.

No-fault is not the only possible policy reform option at the federal and state level. Other potential options include strict liability (liability which does not depend on actual negligence or intent to harm), safe harbor provisions, or even a National Connected and Autonomous Vehicle Injury Compensation Program (inspired by the federal vaccine injury program). Any potential policy reform should be evaluated on how it affects key societal and risk management policy concerns, such as public safety, the deployment of AV technology, crash prevention and rehabilitation, the cost of insurance to consumers and businesses, access to justice and reducing social inequity associated with transportation.

Efficiency and circularity

Reimagining vehicle design standards and specifications, fuel economy and emissions standards would do much to address the policy challenges that stand in the way of reimagining mobility. However, there are other important areas that require policymakers' attention. For example, new and original policy thinking is required in the United States about the strategic benefits of a circular economy for vehicles.

In a circular economy, all forms of waste, including scrap metal and obsolete electronics, are returned to the economy, or used more efficiently. This can provide a way to not only protect the environment, but use natural resources more wisely, develop new sectors, create jobs, and develop new capabilities. Circularity also benefits individual consumers directly by increasing product longevity and repairability, enabling more affordable mobility through new models of purpose-built mobility services and vehicle access, and reduced pollution and negative environmental impacts in communities.[344]

In the United States there is currently no federal end of life vehicle (ELV) recycling policy or framework of incentives. This can be contrasted with the new incentives being offered for lithium-ion car battery recycling in the BIL and mandates on American battery components in the IRA. The policy gap in the United States also contrasts with the advanced ELV recycling frameworks in other major automotive manufacturing regions such as the European Union, Japan, Korea, and China. Although the United States' market driven approach to vehicle and battery recycling has broadly worked well to date, this circular economy and recycling policy gap is a problem because it inhibits the strategic resiliency and reliability of the U.S. supply of materials essential to vehicle manufacturing and clean energy technologies. Policies supporting end of life vehicle recycling could maximize recovery of all the useful materials in automobile parts, strengthen supply chain resiliencies and minimize environmental impact. This is particularly relevant in the context of black mass as discussed previously. New policy in these areas could complement and accelerate investments in in the IRA and BIL towards the automotive sector and critical mineral supply chains.

[342]Anderson, J. M., Heaton, P., & Carroll, S. J. (2010). What Happened to No-Fault Automobile Insurance? RAND Corporation.

[343]Torts of the Future: Autonomous Vehicles. (2018). U.S. Chamber Institute for Legal Reform. [344]See for example Ben Dror, M., Gupta, A., Deloison, T., Schmidt, A., Hoist, A., & Machur, W. (2022). Driving Ambitions: The Business Case for Circular Economy in the Car Industry. World Economic Forum.

[344]See for example Ben Dror, M., Gupta, A., Deloison, T., Schmidt, A., Hoist, A., & Machur, W. (2022). Driving Ambitions: The Business Case for Circular Economy in the Car Industry. World Economic Forum.

Conclusion: Charting a Path Forward for a Reimagined Mobility System

The dawn of a reimagined mobility system presents a powerful opportunity to improve economic productivity and people's quality of life and freedom. However, this potential has not yet been realized and will not be without concrete steps to address the barriers to progress: policy, consumer demand and acceptance, and market challenges.

The current policy landscape suggests a pressing need for policymakers to lead development of a national strategy, establish a unified policy framework, coordinate across levels of government, eliminate dated regulations that stymie innovation, and foster policies that are in tune with the emerging mobility landscape. Without this focused approach to change, the United States will continue to struggle to make meaningful progress and will fail to realize the broad ranging benefits of our global peers.

The clock is ticking. With China already making huge strides in the realms of advanced transportation and communication technologies, a failure to take swift action risks forfeiting the leadership mantle in these transformative sectors. While significant strides have been made in implementing strategic industrial and digital technology policies, courtesy of policies like the IRA and BIL, there is still much ground to cover.

THE IMPLEMENTATION OF A STRATEGY WILL REQUIRE U.S. POLICYMAKERS TO:

- **Put people first** and provide consumers what they need and want in the safest, cleanest and least expensive forms possible.
- **Designate reimagined mobility as a national and economic security priority;**
- **Action an all-of-government digital industrial policy** that will serve as a foundation for the specific policies that lean into the national security, economic productivity and human benefits of advanced transportation technologies and their convergence with digital communications;
- **Scrap outdated regulations and policy structures** that impede the United States' ability to lean into reimagined mobility; and
- **Create and accelerate entirely new policy frameworks that will facilitate a reimagined mobility future** while supporting U.S. and allied innovators to develop and scale new transportation and logistics solutions.

Yet policy alone will not unlock the potential of a 21st century mobility system. The task also demands confronting broader societal challenges, including skepticism from consumers, hesitancy from industries, and a workforce grappling with the changes such technologies bring. Furthermore, there is the need to understand and unwind the traditional vested interests deeply rooted in the current transportation system. There is a need to convene the public and private sectors and work out where each can bring their strengths, skills, and authority to solve these big challenges. Our journey to a reimagined mobility system calls for an integrative approach – one that combines a human-centered perspective, with policy innovation, consumer engagement, and financial support. By embracing this holistic strategy, the United States and its allies can not only address policy imperatives but also drive a wider transformational shift, uniting stakeholders across the spectrum.

In this age of mobility evolution, ReMo envisions a future where transportation is not just about moving people and goods but advances freedom, choice, and sustainable progress for people. As ReMo charts its work for 2024 and beyond the organization will lead in three key areas that will contribute to realizing the potential of transportation innovation and solving big societal challenges: convening a diverse set of perspectives from the public and private sectors to identify barriers to progress and agree on immediate action that can be taken to address the challenges we face; developing and presenting policy changes that will help to advance the development, testing and deployment of new solutions; and raising the visibility of barriers to progress and instances of success that can inform the public dialogue on transportation mobility. The path forward might be challenging, but with unity, vision, and determination, the promise of a reimagined mobility future can become a reality.

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SAFE is an action-oriented, nonpartisan organization committed to transportation and energy policy solutions to ensure the economic and national security of the United States, its partners, and allies. SAFE has convened business and former military leaders since 2004 to advance secure, resilient, and sustainable energy solutions. Visit secureenergy.org to learn more.

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Transportation Policy that Puts People First

SAFE's **Coalition for Reimagined Mobility (ReMo)** is a global initiative advancing a vision for how new mobility technologies and services can shape transportation outcomes that are more efficient, secure, and resilient for people and planet. Guided by global leaders, ReMo's efforts help develop, scale, and deploy solutions that deliver on the goals of transportation technology and address the system-level dynamics of a global mobility system. For more information visit reimaginedmobility.org.

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