RESEARCH, DEVELOPMENT, AND TECHNOLOGY

STRATEGIC PLAN

Fiscal Years 2022 – 2026

Building a Better Transportation Future for All

U.S. Department of Transportation

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MESSAGE FROM THE SECRETARY

We are entering a transformative era in transportation. Driven by American ingenuity, advances in transportation technology from electric and automated vehicles to drones and commercial space travel are creating new possibilities for how people and goods move. With President Biden's landmark Bipartisan Infrastructure Law (BIL), we have an opportunity to make once-in-a-generation investments in modernizing our transportation system, which will make travel safer and more convenient, allow goods to move more efficiently, drive economic growth, and help to address the climate crisis.

In pursuing this transformation, we have an obligation to ensure that the transportation system works better for all Americans. We must harness investment and ingenuity to create good paying jobs and ensure that innovative technologies are safe and accessible so that no matter who you are or where you live you will see the benefits of these investments in transportation.

The BIL creates a number of new programs to drive innovation, create jobs, and support the deployment of transformative technologies.

- It provides $500 million in funding to the Strengthening Mobility and Revolutionizing Transportation (SMART) Program, to kickstart a new generation of smart city innovation.
- It invests in University Transportation Centers that work on climate, equity, and innovation—including at Historically Black Colleges and Universities (HBCUs) and other Minority Serving Institutions.
- It enables an Advanced Research Projects Agency for Infrastructure (ARPA-I) to scale up our R&D efforts to keep pace with innovation and to help to drive it.
- It authorizes $50 million per year in funding to establish a new Open Research Initiative to accelerate the achievement of the Department's priorities and goals by funding unsolicited research proposals that yield disruptive technologies with high-impact potential.

In addition, the BIL includes discretionary grant and formula funding programs that provide billions of dollars across the country targeting challenges such as safety, climate mitigation, equity, eco-nomic strength and global competitiveness through technology deployments, data investments, and new approaches to persistent challenges.

These include programs such as Safe Streets and Roads for All, Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT) Program, charging and fueling infrastructure discretionary grants, and the Reconnecting Communities Pilot Program.

The President has emphasized the importance of restoring trust in government through scientific integrity and evidence-based policymaking, such that our world-class scientists are protected from political interference and can think, research, and speak freely. In January 2021, the White House

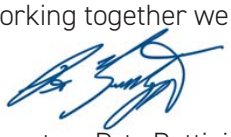
issued an "Executive Order on the President's Council of Advisors on Science and Technology" which stated, "it is the policy of my Administration to make evidence-based decisions guided by the best available science and data." Our Department is committed to maintaining the highest standards in scientific integrity by ensuring that (1) scientists are present at the policymaking table, (2) there is no inappropriate influence or political interference, and (3) there is always free communication of science and research results.

This *U.S. DOT Research, Development, and Technology Strategic Plan for FY2022 – 2026* establishes the Department's leadership role in supporting, fostering, and safeguarding transportation innovation so that it meets our goals and reflects our values. The RD&T Strategic Plan describes the Department's research priorities, objectives, and strategies in support of the Department's strategic goals.

It is also a call to innovation. It takes a collaborative effort across the public, private, academic and non-profit sectors to create a better transportation future. American scientists, teachers, and entrepreneurs are pushing the boundaries of what is possible in transportation. Officials at every level—in cities, towns, counties, States, Tribes and territories - are also seeking new and better ways to meet the needs of the people they serve.

Our role as a Department is to ensure that the enormous potential of U.S. transportation innovation advances our priorities, reflects American values, and ultimately serves to benefit our nation and its people. This means empowering workers and expanding access to training and good jobs with the free and fair choice to join a union. It also means we can't be afraid to do things differently, to experiment and learn from our failures, to seek out opportunities to collaborate across sectors and to remain nimble so that as technologies evolve, America continues to meet the moment and win the future.

Working together we can create a better transportation future for all.



Secretary Pete Buttigieg

LETTER FROM THE DEPUTY ASSISTANT SECRETARY FOR RESEARCH AND TECHNOLOGY

"We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills." When President John F. Kennedy uttered these words in 1962, he inspired a nation and ignited a movement. He foretold the pursuit of our Nation's dream to solve complex problems, overcome seemingly insurmountable challenges, and advance innovations from concepts to deployment.

From the Transcontinental Railroad to the Wright brothers and Apollo 11, transportation has opened new frontiers and ushered in new eras of American innovation. New forms of mobility can shift our perspectives of time, distance, and the world. Transportation innovation sparks human advancement. Our world becomes smaller and more accessible when we illuminate the unknown.

We are now prepared to turn to the next chapter in our Nation's transportation history. The purpose of this *Research, Development, and Technology (RD&T) Strategic Plan* is to provide a national research vision that helps us continue to push the frontiers of transportation innovation. It establishes strategic goals for our Nation's transportation research for the next five years while providing a long-term vision for how research can transform our transportation system to create a better future for all.

These transformative innovations must be broadly accessible, especially to historically underserved communities. So many parts of the modern Civil Rights movement—from the bus boycotts of the 1950s, to the marches from Selma to Montgomery of the 1960s—have focused on the free, safe, and equitable movement of people as fundamental to advancement of civil rights and racial equity. Our physical movement as individuals is deeply tied to movements toward justice, and transportation itself is a powerful catalyst for social and economic mobility.

Our values start and end with the well-being of the people the national transportation system serves. This drives our highest priority: safety. This will never change. Economic disruptions resulting from the Covid-19 pandemic have brought renewed attention to the importance of a strong transportation workforce, a robust freight system, and a resilient supply chain. The climate crisis presents a significant and growing risk to our transportation system, one that will require us to significantly reduce greenhouse gas emissions from our transportation systems. To mitigate and adapt to the impacts of climate change, we will also need to change how we plan, build, protect and operate our transportation system. Further, we know that transportation policy and planning decisions have often exacerbated or perpetuated systemic economic and racial inequality. Addressing these issues requires a robust response from all sectors of society, including transportation.

This is a time of great challenge and uncertainty but it is also a time of remarkable opportunity. This *RD&T Strategic Plan* looks outward to 2050 to explore how evolving technologies may shape our transportation system and policies. We cannot predict how these technologies will reshape our lives or how quickly these transformations may occur. However, we can anticipate dramatic and dynamic changes to our future transportation system. Most importantly, we can define the future we desire and guide the research and innovation that will help us to attain this desired future.

The country must research, engineer, and invest now to prepare for the future we seek. In this time of rapid change and experimentation, research must drive the learning necessary for the public sector to keep pace with technological advancement and to adapt to evolving socio-economic needs. Transformation starts with sound, coordinated research but will require foresight, collaboration, and leadership across all levels of government, academia, and industry.

American leadership in transportation research will help to position the transportation industry to meet rapidly shifting demands and to compete in a global economy. To maintain America's leadership role, we must continue to innovate in new ways.

We offer this *RD&T Strategic Plan* as our national transportation research vision. We believe it will be possible to achieve this vision within a generation, but it will take concerted efforts from many stakeholders working together. Our challenge to you is to join us in this work to make this vision a reality.

Robert C. Hampshire, PhD
Deputy Assistant Secretary for Research and Technology

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INTRODUCTION

To guide America's transportation research priorities

CHAPTER 1

This U.S. Department of Transportation (U.S. DOT, or the Department) *Research, Development, and Technology (RD&T) Strategic Plan (RD&T Strategic Plan)* presents U.S. DOT's transportation research priorities and strategies for the next five years and beyond. The purpose of this *RD&T Strategic Plan* is to outline a national transportation research vision to guide America's research priorities while improving coordination of transportation research. It defines the role of U.S. DOT's RD&T programs to lead the transformation of our Nation's transportation system in partnership with stakeholders.

This *RD&T Strategic Plan* will guide Federal transportation research, development, and technology deployment activities[1] as mandated by 49 U.S.C. §6503. This includes more than $5 billion in research activities funded through the Bipartisan Infrastructure Law (BIL), also known as the Infrastructure Investment and Jobs Act (IIJA) (Pub. L. No. 117-58). The BIL establishes policies, investments, and partnerships that together will provide a once-in-a-generation opportunity to transform our Nation's transportation system.

This *RD&T Strategic Plan* reflects input from a wide range of stakeholders and integrates the research and development (R&D) programs of all U.S. DOT Operating Administrations (OAs) and the Office of the Secretary (OST). The transformation envisioned in this document relies on the strength and creativity of stakeholders across the entire transportation ecosystem, including State, local, Tribal and territorial governments; universities, community colleges, and research labs; organized labor; small businesses and entrepreneurs; the non-profit and philanthropic sectors; and other industry partners.

NATIONAL TRANSPORTATION RESEARCH VISION

We envision a people-centered transportation system that provides safe, accessible, reliable, equitable, and sustainable transportation for all through purpose-driven research and innovation for this and future generations.

We have entered a transformative era for transportation. This transformation is blurring boundaries between traditional transportation domains, enabling a vast array of technological innovations and fostering public awareness of the highly interconnected, multimodal, complex nature of modern transportation. Transportation is not

1 Although the statutory language in 49 U.S.C. Chapter 65 (Research Planning) is limited to research and development (R&D) activities, the Department includes a "technology" component in its reporting and budgeting. The technology component represents Departmental resources and activities allocated to the technology transfer and deployment of R&D results. The Department considers it to be an important part of its role to ensure that research results are fully leveraged in the transportation system. Thus, this *RD&T Strategic Plan* includes the Department's strategic approach to technology transfer and deployment.

just about how people or things move from one place to another. It is also about how we connect, build, consume, work and support communities. Transportation is a complex system-of-systems through which people, technologies, and infrastructure interact. Understanding the interdependent components of the transportation system is key to effectively assessing unintended consequences, imagining potential futures, and selecting robust and adaptive strategies to mitigate risks and achieve desired outcomes.

In this time of rapid change, innovation, and experimentation, research must drive the learning necessary for the public sector to keep pace with technological advancement and adapt to evolving socio-economic needs. Transforming the transportation system will require collaboration across all levels of government, academia, and industry. This transformation starts with sound, coordinated research. American leadership in transportation research will also position the transportation industry to meet rapidly shifting demands and to compete in a global economy.

That leadership starts with a vision to build a better transportation future for all. In this people-centered vision, the needs of people drive the purpose of research efforts rather than the development of technology for its own sake. Research informs and guides a proactive agenda to transform our transportation system to reflect the values of our nation and to benefit society. This people-centered perspective and sense of purpose drives our national transportation research vision.

ACHIEVING BETTER TRANSPORTATION FOR ALL

Addressing big and complex challenges such as climate change, equitable access to transportation, creating good jobs, and the efficiency and resilience of global supply chains will require a whole-of-government approach. To meet these challenges, this *RD&T Strategic Plan* seeks to guide and inspire research not just within the Department but across the Federal Government and the nation through a series of "Grand Challenges." The Grand Challenges describe desired outcomes related to our vision for a better transportation future made possible by purpose-driven research and technology. While they do not denote a specific grant or research program; they are intended to serve as a "call to innovation" to transportation researchers, entrepreneurs, and public policy-makers.

These Grand Challenges are to achieve:

- **Zero Fatalities:** Advance a future without transportation-related serious injuries and fatalities.
- **Resilient Supply Chains:** Create an integrated multimodal freight system that can withstand and rapidly recover from severe disruptions.

- **Equitable Mobility for All:** Create an equitable transportation system that provides safe, affordable, accessible, multimodal transportation options for all users, and where individuals and communities have a greater voice in transportation decisions affecting them.
- **Net-Zero Emissions:** Create a transportation system that supports an economy with net-zero greenhouse gas emissions.
- **The Future Transportation System-of-Systems:** Develop connected intelligent infrastructure that provides people-centered mobility.

GUIDING DOCUMENTS AND STATUTORY REQUIREMENTS

This *RD&T Strategic Plan* is the core document that translates statutory requirements, U.S. DOT strategic goals, and innovation priorities into a cohesive research strategy that guides the Department's research and technology activities for the next five years and beyond. These guiding documents and statutory requirements are shown in the top row of Figure 1 and described in subsequent chapters of this document.

The bottom row of Figure 1 shows mandated plans, reports, and funding processes that are guided by this *RD&T Strategic Plan.* These mandated reports are discussed further in Chapter 4. This *RD&T Strategic Plan* will be used as a reference document for research grants and contracts awarded by the Department to ensure that such awards further the strategic goals and research priorities of the Department.

Figure 1. *U.S. DOT Research Guiding Documents*

PRIMARY PURPOSES

The research priorities, objectives, and strategies described throughout this *RD&T Strategic Plan* support the primary purposes of U.S. DOT transportation research and development program as defined in 49 U.S.C. Chapter 65 (Research Planning):

- Improving mobility of people and goods;
- Reducing congestion;
- Promoting safety;
- Improving the durability and extending the life of transportation infrastructure;
- Preserving the environment;
- Preserving the existing transportation system; and
- Reducing transportation cybersecurity risks.

To accomplish these purposes the Department may pursue the following types of research:

- Fundamental research pertaining to the applied physical and natural sciences;
- Applied science and research;
- Technology development research; and
- Social science research.

U.S. DOT STRATEGIC GOALS

The research priorities, objectives, and strategies described in this *RD&T Strategic Plan* support and are aligned with U.S. DOT's strategic goals. As established in the *U.S. DOT Strategic Plan for FY2022-FY2026 (Strategic Plan)*, the Department's strategic goals are:

- **Safety:** Make our transportation system safer for all people. Advance a future where transportation-related serious injuries and fatalities are eliminated.
- **Economic Strength and Global Competitiveness:** Grow an inclusive and sustainable economy. Invest in our transportation system to provide American workers and businesses reliable and efficient access to resources, markets, and good-paying jobs.

- **Equity**: Reduce inequities across our transportation systems and the communities they affect. Support and engage people and communities to promote safe, affordable, accessible, and multimodal access to opportunities and services while reducing transportation-related disparities, adverse community impacts, and health effects.
- **Climate and Sustainability:** Tackle the climate crisis by ensuring that transportation plays a central role in the solution. Substantially reduce greenhouse gas emissions and transportation-related pollution and build more resilient and sustainable transportation systems to benefit and protect communities.
- **Transformation:** Design for the future. Invest in purpose-driven research and innovation to meet the challenge of the present and modernize a transportation system of the future that serves everyone today and in decades to come.
- **Organizational Excellence:** Strengthen our world-class organization. Advance the Department's mission by establishing policies, processes, and an inclusive and innovative culture to effectively serve communities and responsibly steward the public's resources.

U.S. DOT INNOVATION PRINCIPLES

The Department has established a set of six guiding principles for its work on innovation in transportation. American entrepreneurs and researchers are pushing the boundaries of what is possible in transportation. Federal researchers are working to support and prepare for these developments, to ensure that innovations evolve in ways that are safe, equitable, and sustainable. In the years ahead, the Department's innovation principles will guide that work. Together, these principles will ensure that the enormous potential of U.S. transportation innovation advances the Department's strategic goals, reflects American values, builds economic strength, and ultimately serves to benefit our nation and its people.

- **Serve our policy priorities.** Biden-Harris Administration goals around creating high-quality jobs, achieving racial equity, increasing opportunity for all Americans, and tackling the climate crisis should drive innovation in the Department. Innovations should reduce deaths and serious injuries on our Nation's transportation network, while committing to the highest standards of safety across technologies.
- **Help America win the 21st century.** The Department must play a meaningful role in future-proofing infrastructure, enabling adaptability and resilience, and helping communities and public sector partners to bring legacy transportation systems into the digital age.
- **Support workers.** The Department will empower workers and expand access to skills, training, and the choice of a union. They will have a seat at the table in shaping innovation.

- **Allow for experimentation and learn from failure.** The Department is committed to supporting public sector experimentation, sharing insights, and embracing open data and transparency, while protecting privacy. That means elevating lessons learned from both successful deployments and those that fall short.
- **Provide opportunities to collaborate.** The Department will embrace public-private partnerships that share risk, foster purpose-driven innovation and protect the interests of the public, workers, and communities. The Department must encourage an outcomes-based approach that is technology-neutral.
- **Be flexible and adapt as technology changes.** The Department should identify opportunities for interoperability among innovations and foster cross-modal integration. In addition, U.S. DOT's posture must remain nimble, with a commitment to supporting technologies that further our policy goals.

RESEARCH PROGRAM OVERVIEW

Eight of the Department's OAs and the Intelligent Transportation Systems Joint Program Office (ITS JPO) conduct most of U.S. DOT's research activities. These agencies are:

- Federal Aviation Administration (FAA);
- Federal Highway Administration (FHWA);
- Federal Motor Carrier Safety Administration (FMCSA);
- Federal Railroad Administration (FRA);
- Federal Transit Administration (FTA);
- Maritime Administration (MARAD);
- National Highway Traffic Safety Administration (NHTSA);
- Pipeline and Hazardous Materials Safety Administration (PHMSA); and
- Intelligent Transportation Systems Joint Program Office.

Figure 2 describes the missions of the Department's OAs and joint program office and summarizes the range of entities with which they engage.

Figure 2. *Missions of U.S. DOT Operating Administrations and Joint Program Office*

FEDERAL AVIATION ADMINISTRATION

The Federal Aviation Administration provides the safest and most efficient aviation system in the world. Annually, FAA manages over 54 million flights, approaching a billion passengers.

FEDERAL HIGHWAY ADMINISTRATION

The Federal Highway Administration is responsible for providing stewardship over the construction, maintenance, and preservation of the Nation's highways, bridges, and tunnels. Through research and technical assistance, the FHWA supports its stakeholders in Federal, State, and local agencies to accelerate innovation and improve safety and mobility.

FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION

The Federal Motor Carrier Safety Administration's mission is to reduce crashes, injuries, and fatalities involving large trucks and buses. FMCSA partners with industry, safety advocates, and State and local governments to keep the Nation's roads safe and improve commercial motor vehicle (CMV) safety through regulation, education, enforcement, research, and technology.

FEDERAL RAILROAD ADMINISTRATION

The Federal Railroad Administration's mission is to enable the safe, reliable, and efficient movement of people and goods for a strong America. FRA is committed to advancing the use of new technology in rail.

FEDERAL TRANSIT ADMINISTRATION

The Federal Transit Administration provides financial and technical assistance to local public transit systems, including buses, subways, light rail, trolleys, and ferries. FTA also oversees safety measures and helps to research next-generation technologies.

MARITIME ADMINISTRATION

The Maritime Administration promotes the use of waterborne transportation and its seamless integration with other segments of the transportation system, and the viability of the U.S. Merchant Marine.

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

The National Highway Traffic Safety Administration's mission is to save lives, prevent injuries, and reduce the economic costs of road traffic crashes through education, research, safety standards, and enforcement activity. NHTSA carries out highway safety programs by setting and enforcing safety performance standards for motor vehicles and equipment, identifying safety defects, and by developing and delivering effective highway safety programs for State and local jurisdictions. NHTSA also sets and administers corporate average fuel economy standards for light-duty vehicles and corporate average fuel efficiency standards for medium- and heavy-duty vehicles.

PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION

The Pipeline and Hazardous Materials Safety Administration protects people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. To do this, PHMSA establishes national policy, sets and enforces standards, educates, and conducts research to improve hazardous materials transportation and pipeline safety.

INTELLIGENT TRANSPORTATION SYSTEMS JOINT PROGRAM OFFICE

The Intelligent Transportation Systems Joint Program Office leads collaborative and innovative research, development, and implementation of intelligent transportation systems technologies in surface transportation to improve safety and mobility for all.

Each OA and joint program office has its own mission, statutory requirements, and funding sources. Each develops an Annual Modal Research Plan (AMRP) that describes how it intends to address the Department's strategic goals and priorities in the coming fiscal year. As mandated by 49 U.S.C. Chapter 65, AMRPs must also align with this *RD&T Strategic Plan.*

DEVELOPMENT OF THIS PLAN

The Office of the Assistant Secretary for Research and Technology (OST-R) led the preparation of this *RD&T Strategic Plan*, with collaborative input from the Department's OAs and the Office of the Secretary. In the spirit of innovation and collaboration, this document also incorporates input from numerous U.S DOT stakeholders as well as members of the general public. Comments on U.S. DOT research priorities were received through a Request for Information and a public "Call for Ideas." To solicit expert input, U.S. DOT hosted a virtual workshop with transportation research thought leaders from across the nation. In addition, OST-R consulted with research and policy leads across the Department as well as with transportation research program leads in other Federal agencies. The inputs from these listening sessions and consultations shaped the priorities and strategies identified in this document.

STRUCTURE OF THIS PLAN

The following Chapter (Chapter 2) describes the research priorities, objectives, and strategies in support of five of the six Department's strategic goals: Safety, Economic Strength and Global Competitiveness, Equity, Climate and Sustainability, and Transformation (see also Table 1). U.S. DOT's strategic goal of Organizational Excellence is not directly addressed in this *RD&T Strategic Plan*, but it is a focus of the Department's technology transfer and deployment activities described in Chapter 3. Chapter 4 describes U.S. DOT's activities to oversee and monitor Departmental research and to measure and evaluate research performance in accordance with this *RD&T Strategic Plan*.

This *RD&T Strategic Plan* includes the following elements:

- **Strategic Goals.** These goals are drawn directly from the Department's Strategic Plan and guide U.S. DOT research priorities, objectives, and strategies.
- **Research Priorities** represent multimodal research focus areas and opportunities for future coordination across the Department and with other Federal agencies and external stakeholders.
- **Research Objectives** describe the research objectives the Department seeks to achieve within each research priority.

- **Research Strategies** describe the types of research activities in which the Department plans to engage to make progress towards the research objectives.
- **Grand Challenges** present visions of a better future for our Nation's transportation system made possible by the research and innovation of stakeholders across the public, private, academic, and other sectors (see Table 1 for additional description). These challenges do not denote a specific research or grant program rather they are intended to inspire broad research and technology development efforts from a wide range of stakeholders towards a shared vision.

Table 1. *Strategic Goals, Research Priorities, and Grand Challenges*

STRATEGIC GOALS	RESEARCH PRIORITIES	GRAND CHALLENGES
Safety	• Human Factors • Data-Driven System Safety • Cybersecurity	**Zero Fatalities:** Advance a future without transportation-related serious injuries and fatalities.
Economic Strength and Global Competitiveness	• Resilient Supply Chains • Advanced Asset Management • System Performance • Create Pathways to Good Quality Jobs	**Resilient Supply Chains:** Create a multi-modal freight system that can withstand and rapidly recover from severe disruptions.
Equity	• Equity and Accessibility Assessment • Mobility Innovation • Wealth Creation	**Equitable Mobility for All:** Create an equitable transportation system that provides safe, affordable, accessible, and convenient mobility options for all users.
Climate and Sustainability	• Decarbonization • Sustainable and Resilient Infrastructure	**Net-Zero Emissions:** Create a transportation system that supports an economy with net-zero greenhouse gas emissions.
Transformation	• Integrated System-of-Systems • Data-Driven Insight • New and Novel Technologies	**The Future Transportation System-of-Systems:** Develop connected intelligent infrastructure that provides people-centered mobility.

RESEARCH PRIORITIES, OBJECTIVES, AND STRATEGIES

CHAPTER 2

SAFETY

Safety is U.S. DOT's top priority and remains a major challenge for our nation's transportation system.

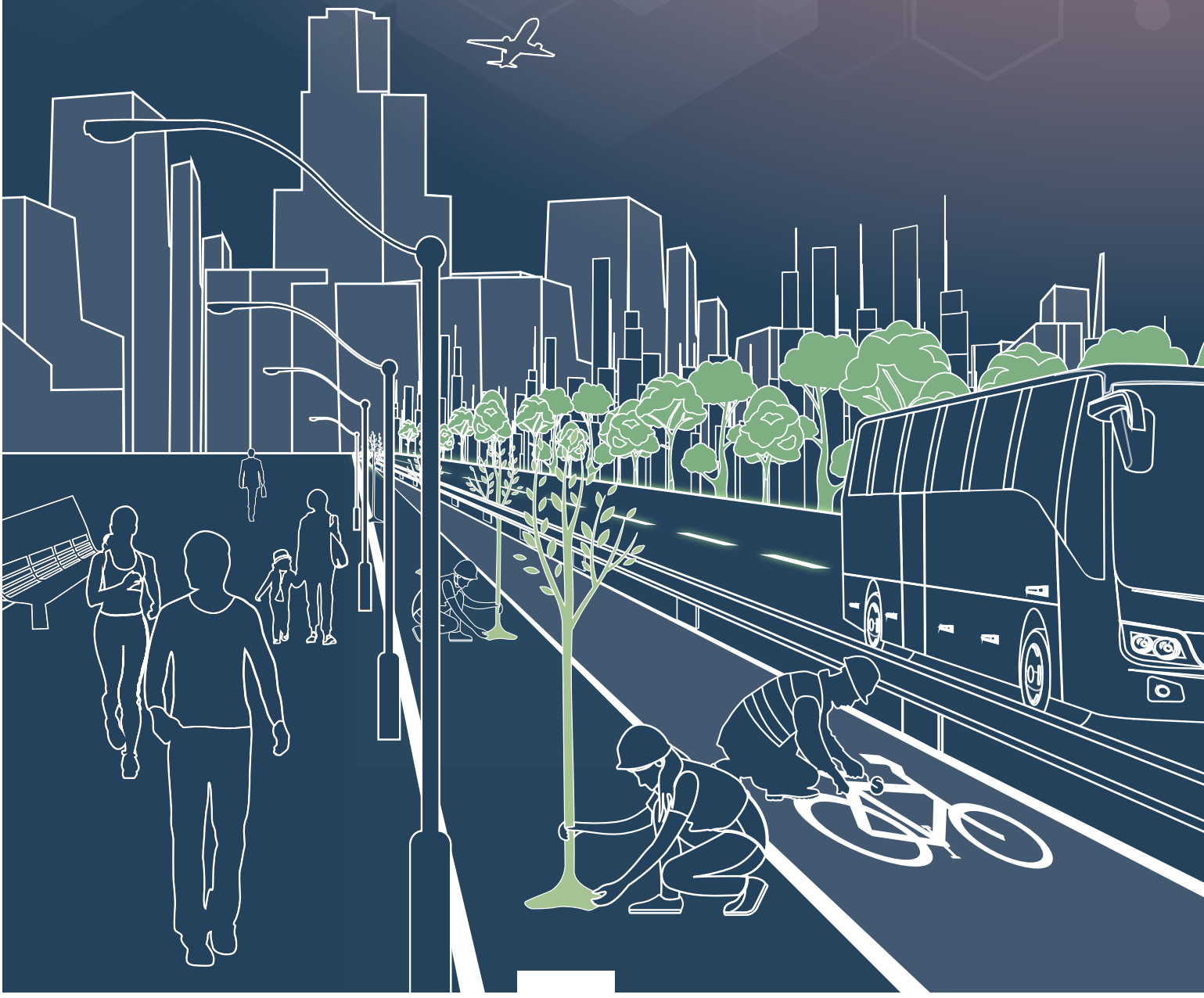
There were more than 43,000 fatalities on the U.S. transportation system in 2021. Almost 95 percent of those deaths occurred on America's streets, roads, and highways, and deaths are on the rise. In 2021, a year when vehicle travel was down overall, 42,915 people died in motor vehicle crashes—more than 100 deaths per day. Millions more were injured. U.S. DOT's safety RD&T efforts aim to contribute to a future transportation system where transportation-related serious injuries and fatalities are eliminated.

The Department's safety research provides new insights into transportation safety challenges and mitigation strategies that leverage data, technology, and research across multiple disciplines to improve safety outcomes. Advances in technology, engineering, data science, and human factors research are changing how the Department and transportation safety stakeholders are assessing and addressing transportation safety risks in all modes of transportation. The Safe System Approach, a strategy to address the Nation's traffic safety problem that is the foundation for the National Roadway Safety Strategy, is a prime example of this multidisciplinary, holistic approach to transportation safety. Safety RD&T also includes work to understand and address human factors; design and build safer transportation infrastructure, vehicles, and systems; strengthen cybersecurity; and protect travelers and communities from transportation health and safety risks, including those posed by the transport of hazardous materials.

SAFETY
GRAND CHALLENGE

ZERO FATALITIES

Advance a future without transportation-related serious injuries and fatalities.



SAFETY GRAND CHALLENGE

CRITICAL RESEARCH TOPICS:

- Operator fatigue, distraction, and performance
- Safety equity analysis
- Safety infrastructure countermeasures
- Safety risk analysis methods
- Speed management
- Vehicle and aircraft safety, automation, and connectivity
- Vulnerable road user safety

VISION: Together, we must strive for zero transportation system fatalities. Zero is the only acceptable number of deaths and serious injuries on our transportation system. Achieving the vision of zero fatalities will take effort from across society to change how we design and operate our transportation system.

DESIRED OUTCOMES:

- People no longer accept a high risk of fatality or serious injury as a cost of mobility. Social norms have changed. Impaired, risky, and distracted driving is no longer accepted, and everyone wears a seatbelt.
- Work zones operate safely and the safety of our transportation workers and first responders is assured.
- Vehicle and aircraft designs incorporate proven, active and passive safety features that protect vehicle occupants and non-occupants.
- Improvements to infrastructure designs reduce the risk of severe crashes by managing speeds, reducing conflicts, and mitigating the effects of crashes.
- Accessible, connected bicycle and pedestrian networks are built out to enable safe and comfortable non-motorized travel.
- Transit, shared mobility services, and passenger trains provide convenient and affordable alternatives to driving for many trips.
- The transportation system safely accommodates the accessibility needs of people with disabilities.
- Emergency response times are shortened so that when crashes occur, victims receive effective treatment sooner and crashes are cleared more quickly to prevent secondary crashes.
- People lead healthier, more active lives, and live longer—no matter who they are or where they live. Insurance rates are lower, and people have fewer crash-related medical expenses. Law enforcement can focus on other needs besides clearing crash scenes.

Table 3. *Safety Research Priorities and Objectives*

RESEARCH PRIORITIES	RESEARCH OBJECTIVES
Human Factors	• **Safety Culture and Behavior:** Improve the understanding of attitudes and behaviors toward transportation system safety and support changes to reduce unsafe behaviors and promote safe travel. • **Human-Technology Interactions:** Improve the understanding of how human interactions with technology can affect transportation safety to support the development and use of safer technologies and designs.
Data-Driven System Safety	• **Safe Design:** Evaluate the safety performance of infrastructure design and develop and promote the use of effective safety countermeasures. • **Safety Data:** Develop new methods and tools for safety data collection, management, analysis, and evaluation. • **Safe Technology:** Advance transportation safety by evaluating the safety of existing transportation technologies and supporting the safe integration of emerging technologies. • **Hazardous Material Safety:** Conduct research to improve the safety of hazardous materials transportation.
Cybersecurity	• **Cybersecurity Risk Analysis:** Assess cybersecurity risks to connected digital systems. • **Cybersecurity Standards:** Support the development and use of cybersecurity standards and best practices.

RESEARCH PRIORITY: HUMAN FACTORS

U.S. DOT human factors research investigates sources of user error that can lead to transportation safety incidents, such as fatigue, impairment, and operator performance. This research advances the understanding of how to support the adoption of a transportation safety culture; design systems to improve human performance and reduce the risks associated with use error; promote safe behaviors; and reduce risky behaviors. In an era of rapidly evolving transportation technologies, human factors research also focuses on interactions with technology and analyzes the potential for distraction or misunderstanding of the capabilities and limitations of new technologies.

Safety Culture and Behavior: Improve the understanding of attitudes and behaviors toward transportation system safety, and support changes to reduce unsafe behaviors and promote safe travel.

- Conduct research to understand and prevent destructive traffic safety behaviors such as speeding, drug- and alcohol-impaired driving, and inattentive and distracted driving.
- Improve the understanding of operator fatigue and stress and develop tools to help operators manage fatigue and stress.
- Identify and assess the root causes of rail grade crossing and trespass incidents to develop strategies to prevent future incidents.
- Understand the causes of and address disparities in traffic safety enforcement and develop strategies to prevent them.
- Assess and address the causes of racial, ethnic, and gender disparities in transportation safety.
- Understand human transportation mode choices, risk perception, and how to help people return to shared transportation modes, such as public transit and commercial air travel.

Human-Technology Interactions: Improve the understanding of how human interactions with technology can affect transportation safety to support the development and use of safer technologies and designs.

- Learn how people respond to the roadway environment, including signs, markings, and traffic control devices, emerging vehicle and roadway technology, innovative operational changes, and pedestrian and bicyclist safety.
- Explore the effects of new technologies, including automation, on travel behaviors.
- Address human factors challenges related to air traffic control and cockpit digitization.

RESEARCH PRIORITY: DATA-DRIVEN SYSTEM SAFETY

Multiple factors contribute to transportation-related fatalities and serious injuries. Research and data are essential for understanding the systemic causes of transportation safety challenges. Effective use of performance-based standards, policies, and regulations require reliable data, effective analytical tools, and a broad awareness and understanding of risk management practices. Efforts in this area consider how technological innovations can reduce and mitigate crashes, how regulatory and policy tools can reduce fatalities and injuries, how optimized system designs can improve safety, and how to mitigate risks associated with the transport of energy and hazardous materials.

Safe Design: Evaluate the safety performance of infrastructure design and develop and promote the use of effective safety countermeasures.

- Perform research to support the development of training, policy guidance, and technical assistance to aid implementation of a Safe System approach.
- Identify and support strategies to increase vulnerable road user safety (e.g., pedestrians, bicyclists, motorcyclists, and people with disabilities).
- Develop and promote effective methods to assess and address traffic safety risks in rural and underserved communities.

Safety Data: Research and develop new methodologies and tools for safety data collection, management, analysis, and evaluation.

- Develop safety data collection methods and advanced safety data and risk analysis techniques to identify and analyze emerging safety issues.
- Provide the scientific and engineering basis for policy decisions, improved industry standards, and enforcement and compliance matters.
- Assess safety incident trends and causes to enhance safety requirements and best practices.
- Improve safety data systems and integration of other data sources to improve analysis and identify emerging safety risks and disparate safety impacts on people and communities.

Safe Technology: Advance transportation safety by evaluating the safety of existing transportation technologies and supporting the safe integration of emerging technologies.

- Develop test tools, procedures, and performance measures that enable improved safety, durability, resiliency, and crashworthiness evaluations of aircraft, rail cars, ships, and vehicles.
- Build an evidence basis to support performance-based Federal safety standards and regulations for transportation technologies.
- Leverage innovative technologies to monitor, predict, and plan ways to reduce injuries and fatalities among the transportation workforce and traveling public.
- Evaluate the effect of transportation technologies on safety outcomes for vulnerable populations.
- Support the development, evaluation, and implementation of connected digital infrastructure designed to enhance transportation safety outcomes.

Hazardous Material Safety: Conduct research to improve the safety of hazardous materials transportation.

- Assess the safety of emerging transportation fuels including advanced battery, stored gas, and fuel cell technologies.
- Evaluate the packaging, carriage, and transport of hazardous materials and develop mitigation strategies to improve their safety.
- Improve anomaly detection, such as leak detection, at storage facilities or when transporting hazardous materials in order to reduce potential impacts on public health and the environment.

RESEARCH PRIORITY: CYBERSECURITY

Transportation systems are increasingly reliant on connectivity to communicate and to exchange data. While increasing connectivity can yield significant benefits to providers and consumers of transportation services, increasing interdependencies across the transportation sector raise the potential for cyberattacks and failures that could damage critical transportation services and assets. Further, due to the widespread adoption of positioning, navigation, and timing (PNT) services such as GPS, the disruption or manipulation of these services has the potential to adversely affect the security and safety of the transportation system and of the Nation as a whole. Defensive security practices could be outpaced by evolving threats unless more advanced technologies are adopted to enable rapid detection, analysis, response, and recovery from cyber-events. Federal leadership is critical to ensuring that State, local, Tribal, and territorial agencies adopt effective cyber-risk management practices for connected infrastructure and devices and foster the responsible use of PNT services.

Efforts in this area focus on evaluating and incorporating cybersecurity considerations into emerging technologies; strengthening system response and recovery approaches to minimize effects of cyber-attacks; and identifying, assessing, and addressing cyber-vulnerabilities.

Cybersecurity Risk Analysis: Assess cybersecurity risks to connected digital systems.

- Assess the safety vulnerabilities, threats, and risks of complex digital systems.
- Develop risk analysis tools and methodologies to prevent, detect, and respond to cyberattacks to ensure continued safe operations.
- Explore ways to protect safety-critical data to prevent accidental or unauthorized modification, destruction, or disclosure of information.
- Collaborate with national security agencies to develop a Cyber Incident Response Plan for each OA and a Unified Cyber Incident Response Plan for the Department in accordance with national cybersecurity guidance.

Safe System Approach

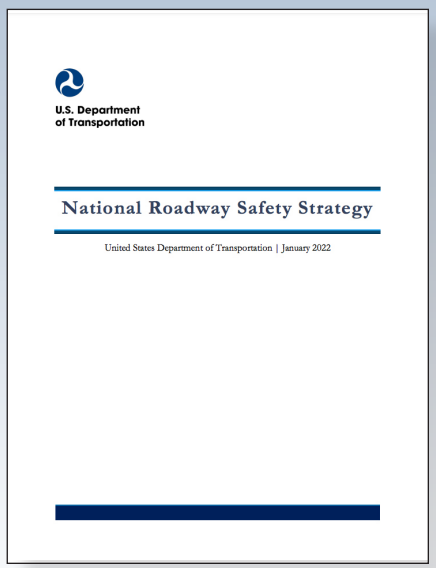
The Safe System Approach starts with a mindset that it is unacceptable to allow deaths and serious injuries to occur on our Nation's roads. It also acknowledges that road users are human beings and that humans will inevitably make mistakes. Human error is to be expected, so road infrastructure and vehicle technology must be designed and operated so that deaths and serious injuries are managed through system safety engineering. This may be achieved first by reducing the risk of errors; and second by keeping collision forces on the human body within tolerable levels when crashes do occur, by managing speed and crash angles to reduce injury severity. The Safe System Approach considers five elements of a safe surface transportation system—safe road users, safe vehicles, safe speeds, safe roads, and post-crash care—in an integrated and holistic manner. The Department's recently released National Roadway Safety Strategy adopts this approach.

Cybersecurity Standards: Support the development and use of cybersecurity standards and best practices.

- Facilitate the implementation of cybersecurity best practices across the transportation system.
- Support enhanced reliability and resiliency of vehicle and aircraft electronics, software, and related control systems.
- Advance the transportation industry's adoption and implementation of the National Institute of Standards and Technology (NIST) Cybersecurity Framework and the NIST Foundational PNT Profile.

National Roadway Safety Strategy

U.S. DOT National Roadway Safety Strategy (NRSS) outlines the Department's comprehensive approach to significantly reducing serious injuries and deaths on our Nation's highways, roads, and streets. The NRSS represents a Department-wide approach to working with stakeholders across the country to achieve this goal. This is the first step in working toward an ambitious long-term goal of reaching zero roadway fatalities and serious injuries.



ECONOMIC STRENGTH AND GLOBAL COMPETITIVENESS

After decades of underinvestment, our infrastructure is failing to keep up with growing transportation needs. Parts of our system have fallen into disrepair. Modernizing our transportation system is essential to creating jobs, growing an inclusive and sustainable economy, and improving quality of life in all communities. Research on this topic supports effective investments in the transportation system to improve the durability, sustainability, and resilience of transportation assets and provide American workers and businesses with reliable and efficient access to good-paying jobs, resources, and markets. U.S. DOT research efforts on this topic pertain to advanced materials and structures; asset management; infrastructure planning, finance, and construction; system operations; freight; and workforce development.

Table 3. *Economic Strength and Global Competitiveness Research Priorities and Objectives*

RESEARCH PRIORITIES	RESEARCH OBJECTIVES
Resilient Supply Chains	• **Freight Planning and Performance:** Develop data and tools to assess freight system performance and support performance-based freight planning and policies. • **Freight Safety and Operations:** Identify and promote tools and practices to improve freight system safety, reliability, and resilience.
Advanced Asset Management	• **Advanced Materials and Structures:** Develop tools, technologies, and guidance to improve infrastructure durability, longevity, and sustainability through innovative materials and structures. • **Asset Management and Inspection:** Advance methods and technologies to inspect, preserve, and maintain infrastructure conditions.
System Performance	• **Performance-Based Planning:** Advance the use of tools and best practices in performance-based transportation planning, policy, and programming. • **Accelerated Project Delivery:** Build the capacity of public agencies to use innovative construction and financing methods to accelerate the delivery and improve the quality of transportation infrastructure. • **Transportation System Management and Operations:** Identify and promote strategies to strengthen the management and operation of multimodal transportation systems.
Creating Pathways to Good Quality Jobs	• **Collect Data and Share Best Practices:** Evaluate and advance best practices concerning workplace equity, job quality, the impacts of new technology on workers, successful training programs, and the role of unions in creating high quality transportation jobs. • **Create High-Quality Jobs and Career Pathways:** Support the creation of good jobs with the choice to join a union through training, capacity building, and registered apprentice programs.

RESEARCH PRIORITY: RESILIENT SUPPLY CHAINS

Research on freight systems supports innovative approaches to freight planning, freight infrastructure funding and development, and freight data collection and maintenance to enhance the safe and efficient movement of goods and to support economic competitiveness. U.S. DOT aims to enhance freight and supply chain system safety, security, efficiency, reliability, and resilience. RD&T efforts in this area include identifying critical supply chain vulnerabilities, supporting more efficient intermodal connections, developing effective strategies to address last-mile delivery challenges, and advancing freight system planning.

Freight Planning and Performance: Develop data and tools to assess freight system performance and support performance-based freight planning and policies.

- Improve the ability to measure current and future conditions and support operation of the freight transportation network through the incorporation of more accurate, real-time, and localized freight data.
- Increase understanding of supply chain performance by improving supply chain data collection, data sharing, and data analysis capabilities.
- Provide data, tools, and technical assistance to support the integration of freight considerations in the transportation planning and programming process.

Freight Safety and Operations: Identify and promote tools and practices to improve freight system safety, reliability, and resilience.

- Conduct research and testing on innovations in the design of freight infrastructure, vehicles, handling and packaging for improved freight safety and performance.
- Identify and promote the use of best practices to enhance the safety and reliability of multimodal freight movements and to address last-mile delivery challenges.
- Evaluate strategies to improve freight system resilience and incorporate supply chain resilience into freight planning.
- Support the adoption of technologies and best practices that enable sustainable and efficient cargo movement at ports.
- Identify strategies to mitigate the negative impacts of freight transportation on communities and the environment.
- Conduct research to improve decision-makers' ability to incorporate equity considerations into commercial motor vehicle inspection and enforcement activities.

ECONOMIC STRENGTH AND GLOBAL COMPETITIVENESS
GRAND CHALLENGE

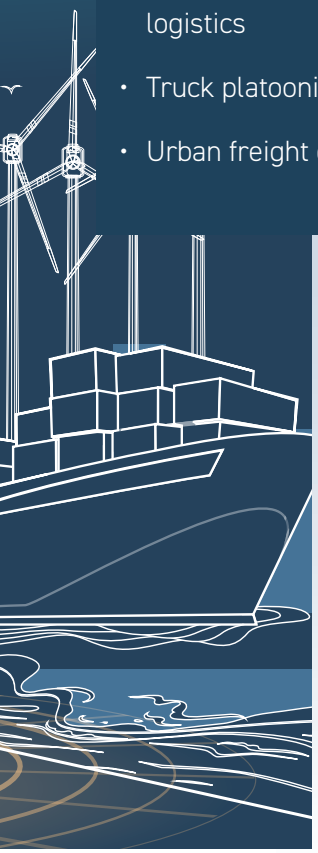
RESILIENT SUPPLY CHAINS

Create multimodal freight system that can withstand and rapidly recover from severe disruptions.

ECONOMIC STRENGTH AND GLOBAL COMPETITIVENESS GRAND CHALLENGE

CRITICAL RESEARCH TOPICS:

- Freight environment and equity impacts
- Freight infrastructure resilience
- Freight planning
- Freight and logistics workforce needs
- Supply chain data and logistics
- Truck platooning
- Urban freight delivery



VISION: Our Nation depends on resilient performance from our freight system and supply chains to support reliable access to goods, create good jobs at home, and improve economic competitiveness abroad. Supply chains are highly complex, interconnected systems. Shocks to any node can affect supply chain system performance in unexpected ways. A resilient freight and supply chain system allows for reliable service after small disruptions and a quick return to service after large disruptions. We envision a world where our Nation's freight system and supply chains are able to withstand and recover quickly from disruptions and sustain American economic leadership in an increasingly competitive global economy.

DESIRED OUTCOMES:

- Freight planners have the data they need to assess the criticality and vulnerability of freight facilities, take multimodal freight and land use needs into account, develop scenario-based plans, and prioritize investments with resilience as a key consideration.
- Freight rail, inland waterway networks, port, and airport facilities are kept in good repair and have sufficient capacity and connectivity to provide reliable and sustainable multimodal options for shippers.
- Timely and accurate data on goods location and movement and analysis driven by artificial intelligence help shippers and transportation partners quickly detect, respond to, and recover from disruptions and changed conditions.
- Freight stakeholders quickly apply dynamic and adaptive practices, such as the use of "pop-up" freight facilities, to accommodate surges in demand and to adjust to disruptions.
- Electrification and the use of alternative fuels to reduce noise impacts and emissions caused by freight activities, and other mitigations are in place to support the quality of life in communities adjacent to freight activities.
- The use of cybersecurity best practices reduces the vulnerability of supply chains to cyberattacks.
- The use of advanced robotics and information and communications technologies make the freight transportation workforce safer and more productive, increase throughput at freight hubs, expedite inspections, and improve the safety and efficiency of freight movements.
- Innovative practices, such as the use of dynamic curbside management policies and load consolidation facilities, are in place to enhance last-mile logistics.
- Workforce training programs and government-labor-industry partnerships improve work conditions and attract a new generation of skilled workers to good-paying jobs in the freight industry.

Advanced Materials

Imagine a future where structural elements and pavements can form, reform, and change shape in reaction to the environment. Smart, self-healing infrastructure technology offers the potential to combine the physical and digital worlds to improve the safety, sustainability, longevity, and resilience of infrastructure. In the future, infrastructure may be equipped with advanced sensing technology that automatically detects structural anomalies or deterioration and notifies officials when it needs to be repaired. Some materials used in transportation infrastructure may even be able to "self-repair" by autonomously sealing cracks using reagents or bacteria embedded in the material. This could improve the longevity of infrastructure, resulting in lower maintenance costs and reduced emissions.

RESEARCH PRIORITY: ADVANCED ASSET MANAGEMENT

Research on materials, structures, and maintenance and repair practices focus on reducing the lifecycle costs of transportation assets and improving their resilience and sustainability. Research includes the development of advanced materials that can enable new infrastructure designs, improve structural resilience, and accelerate construction and repair. To extend the life of existing infrastructure, research is advancing the use of asset management practices and the timely, accurate, and efficient assessment of transportation assets to improve safety, prioritize investments, and enhance the efficiency and effectiveness of maintenance and preservation efforts. Increasingly, these practices are supported by automated inspection technologies, self-reporting sensors, edge computing, and artificial intelligence.

Advanced Materials and Structures: Develop tools, technologies, and guidance to improve infrastructure durability, longevity, and sustainability through innovative materials and structures.

- Advance understanding and improvement of infrastructure material lifecycle costs and improve design methods for preservation, maintenance, and rehabilitation.
- Advance methods to assess the engineering and environmental performance of innovative, high-performance materials.
- Evaluate and promote the use of sustainable and recyclable infrastructure materials.
- Develop and evaluate advanced materials that enable new infrastructure designs, improve structural resilience, and accelerate construction and repair.

Asset Management and Inspection: Advance methods and technologies to inspect, preserve, and maintain infrastructure conditions.

- Develop and promote asset management and performance management principles, practices, and approaches to reduce lifecycle costs and extend the life of assets.
- Advance rapid repair and rehabilitation techniques.
- Advance the use of advanced sensor systems and automated inspection technologies to support early identification of structural deficiencies and infrastructure deterioration.
- Investigate how emerging technology, such as uncrewed aircraft systems (UAS), can augment asset management, preservation, and maintenance practices to improve resilience of structures and pavement.

RESEARCH PRIORITY: SYSTEM PERFORMANCE

Research is needed to strengthen transportation system planning, project delivery, procurement methods, and operations to address multimodal transportation needs. Transportation planning research supports the adoption of planning best practices and the development and use of models and tools to support data-driven investment decisions to meet performance goals. Research efforts in this area also include developing and implementing innovative financing and supporting policy and investment decision-making. Finally, research can support the development and adoption of transportation system management and operations strategies that help reduce congestion and fuel consumption and allow better management of the existing transportation system.

Performance-Based Planning: Advance the use of tools and best practices in performance-based transportation planning, policy, and programming.

- Develop and promote resources that support the integration of transit, pedestrian, bicycle, and micromobility designs and analyses into multimodal network planning and project development, particularly in traditionally underserved communities.
- Identify and promote effective and successful tools and information necessary to integrate pedestrian and bicycle analysis into transportation planning and project development.
- Research the economic, fiscal, and job impacts of transportation investments.
- Research the person-level impacts and outcomes due to transportation investments.
- Evaluate trends and emerging technologies to predict changing travel behaviors and travel needs, and understand implications for transportation policy and investment decisions.
- Perform research to identify, develop, and evaluate strategies to support the integration of land use and transportation planning.
- Research methods to strengthen meaningful and equitable community participation in the transportation planning process.

Accelerated Project Delivery: Build the capacity of public agencies to use innovative construction and financing methods to accelerate the delivery and improve the quality of transportation infrastructure.

- Develop and promote innovative methods to improve the effectiveness and efficiency of infrastructure construction and project management.
- Develop tools, training, and technical assistance to support the use of innovative finance strategies to accelerate the delivery of critical infrastructure projects.
- Assess and promote innovative project revenue options, such as user fees and value capture, to support transportation investments.

Transportation System Management and Operations: Identify and promote strategies to strengthen the management and operation of multimodal transportation systems.

- Develop, test, and evaluate the capability of new technologies to improve transportation systems management and operations.
- Develop tools and guidance to enable more proactive, dynamic, integrated and performance-driven traffic management and incident response.
- Provide scientific and technical information to support the safe and efficient management of air traffic control systems.
- Advance strategies to ensure safe and continuous movement of people and goods during an emergency.

RESEARCH PRIORITY: CREATING PATHWAYS TO GOOD QUALITY JOBS

The transportation sector is rapidly evolving to become one of the most innovative and dynamic areas of the Nation's economy. Developments in robotics, artificial intelligence, sensors, mapping, data, cybersecurity, alternative fuels and electrification, PNT, and connectivity are driving innovations that offer opportunities to significantly advance U.S. DOT's mission. At the same time, these technologies will have far-reaching impacts on the roles and skills required of the transportation workforce. To support the effective use of transformative practices and technologies, the transportation sector must attract and develop a new generation of transportation worker, while supporting the retention and training of the current workforce. RD&T efforts in this area include supporting workforce and educational programs that create and promote opportunities for careers in transportation; enhancing efforts to recruit, develop, hire, and retain a diverse and inclusive workforce; and strengthening the domestic transportation workforce from a supply chain perspective.

Collect Data and Share Best Practices: Evaluate and advance best practices concerning workplace equity, job quality, the impacts of new technology on workers, successful training programs, and the role of unions in creating high quality transportation jobs.

- Identify and evaluate strategies that help to create high quality jobs with good pay and choice to join a union in the transportation sector.
- Evaluate the job creation opportunities and benefits of funding programs.
- Collect data on workplace equity, job quality, and the role of unions in the transportation workforce.
- Evaluate challenges in recruiting, training, and retaining a diverse and inclusive transportation workforce.

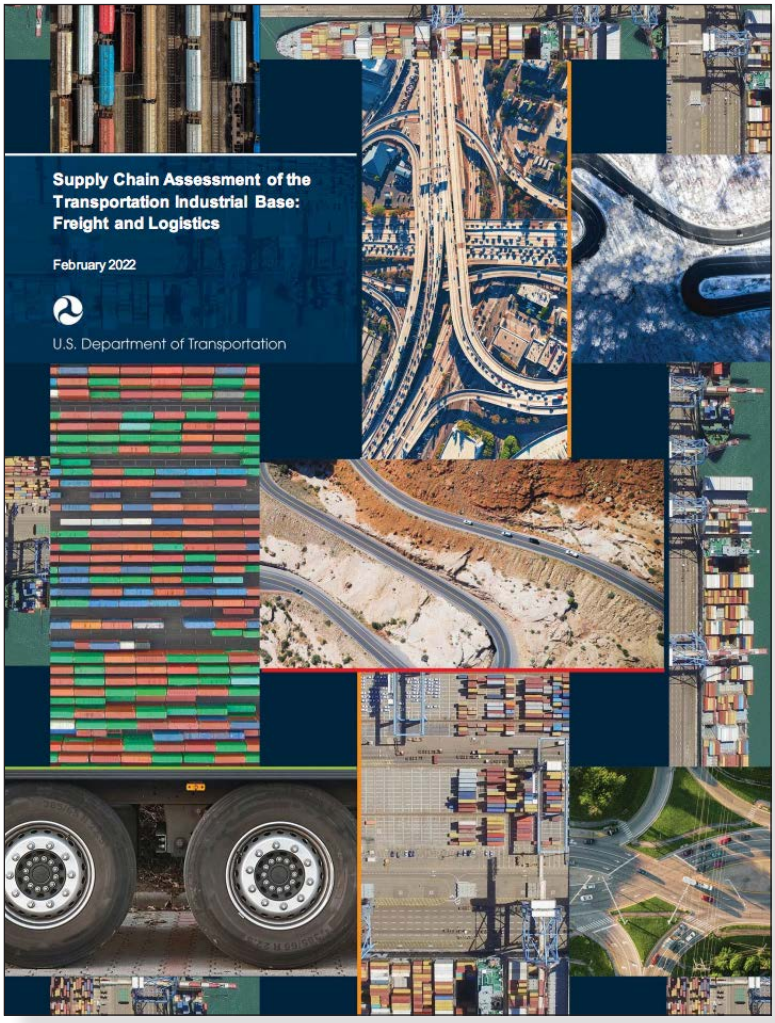
- Assess the extent and causes of workforce shortages in the transportation sector and evaluate strategies that enhance workforce recruitment and retention.
- Analyze the skills and knowledge needed by transportation workers to manage each succeeding generation of information and communications technologies, equipment, and systems.

Create High-Quality Jobs and Career Pathways: Support the creation of good jobs with the choice to join a union through training, capacity building, and registered apprentice programs.

- Support training and capacity building programs to recruit and develop today's transportation workers and those of the next generation.
- Partner with academic institutions, labor, and the private sector to support transportation research and education and to build transportation career pathways and registered apprentice programs.
- Promote the understanding and adoption of proven technologies and best practices that create better jobs and train workers on new technologies.

U.S. DOT Freight and Logistics Supply Chain Assessment

The *U.S. DOT Freight and Logistics Supply Chain Assessment*, released in February 2022, assessed the vulnerabilities in our Nation's freight system and supply chains. The report identified dozens of strategies to build more resilient and efficient supply chains that can withstand the shocks of potential future disruptions, such as large-scale weather events, national health emergencies, or other events. Resilient freight and supply chain systems will better enable response and recovery for significant events, spur economic growth, lower costs for American consumers, and create good-paying jobs. The Biden-Harris Administration has made this work a top priority, including passing BIL, which makes the largest investment in ports in American history, reversing decades of underinvestment in our country's critical freight infrastructure.



EQUITY

A Strategic Goal of the Department is to expand accessibility and mobility to underserved communities, including people with disabilities, older Americans, and rural and disadvantaged communities. Transportation equity considers complex relationships among individuals, communities, the economy, and the environment to enable decision-making outcomes that help meet the needs of all transportation system users. U.S. DOT's transportation equity RD&T activities include efforts to assess equity and accessibility, as well as to develop and promote innovative, equitable, and accessible mobility technology and services.

Table 4. *Equity Research Priorities and Objectives*

RESEARCH PRIORITIES	RESEARCH OBJECTIVES
Equity and Accessibility Assessment	• **Equity and Accessibility Assessment:** Develop data, tools, and research to evaluate and advance the equity and accessibility of transportation systems, projects, jobs, and policies.
Mobility Innovation	• **Mobility Innovation:** Evaluate innovative mobility technologies and services to improve the accessibility, equity, and sustainability of transportation.
Wealth Creation	• **Wealth Creation:** Provide technical assistance to small, disadvantaged businesses, Historically Black Colleges and Universities, and Minority Serving Institutions to navigate U.S. DOT research opportunities and the contracting process, gain awareness of upcoming contract opportunities, and enhance their core competencies and skills.

RESEARCH PRIORITY: EQUITY and ACCESSIBILITY ASSESSMENT

Equity analysis RD&T efforts include collecting data that represents the diversity of transportation system users and developing new analytic tools and frameworks to inform and evaluate decisions that support the equitable treatment of all individuals and communities. Transportation accessibility ensures access for users of all abilities through infrastructure and access to new transportation innovations and technology.

Equity and Accessibility Assessment: Develop data, tools, and research to evaluate and advance the equity and accessibility of transportation systems, projects, and policies.

- Develop and enhance the tools and methods to effectively ensure compliance with Title VI of the Civil Rights Act of 1964, which prohibits discrimination on the basis of race, color, or national origin in any program or activity that receives Federal funds or financial assistance.
- Develop and enhance the tools and methods to effectively ensure compliance with the transportation provisions contained in Titles II & III of the Americans with Disabilities Act of 1990, which prohibits discrimination on the basis of disability regardless of the receipt of Federal funds or financial assistance.
- Develop data and analytical methodologies to measure the transportation needs of underserved and disadvantaged communities, and to ensure traditionally underserved people are afforded equitable access to convenient transportation options through inclusive and efficient multimodal transportation planning.
- Conduct research to assess the transportation needs and challenges of women , people of color, and the LGBTQI+ community.
- Research ways to mitigate or ease transportation barriers for people with physical, sensory, and cognitive disabilities.
- Develop tools and methods to measure the accessibility of transportation infrastructure.
- Conduct research to identify and evaluate socio-economic disparities in the distribution of environmental impacts of transportation activities.

RESEARCH PRIORITY: MOBILITY INNOVATION

Millions of Americans do not have the option of driving to get where they need to go due to cost, age, disability, or lack of access to training to obtain a driver's license. Many others prefer not to drive. Public transportation meets the transportation needs of millions of Americans, but is not available everywhere, and where it exists, is not able to serve all trips and needs. Bringing together progress in enabling technologies like communications, data analysis, and clean energy with innovations in business models and service design creates new opportunities for people to get where they need to go, when they want to get there, at a price they can afford. Innovations in mobility may serve as a complement to transit, providing additional safe, affordable, and convenient transportation options for all Americans.

Mobility innovation research studies the use of innovative practices and emerging business models and technologies to expand access and improve mobility for Americans, particularly for rural residents and people with disabilities. In recent years, innovative technologies and business models have expanded mobility options and improved transportation system reliability. Many new transportation business models have emerged in the past decade that leverage smartphone and global

EQUITY
GRAND CHALLENGE

EQUITABLE MOBILITY FOR ALL

Create anequitable transportation system that provides safe, affordable, accessible, and convenient mobilityoptions for all users.

EQUITABLE MOBILITY FOR ALL GRAND CHALLENGE

CRITICAL RESEARCH TOPICS:

- Assistive and accessible mobility innovations
- Equity, affordability, and accessibility analysis
- Environmental justice
- Mobility justice and resilience
- Transportation planning and land use
- Alternative traffic safety enforcement strategies

VISION: Imagine a world where no matter where you live, how much money you have, or who you are, you have access to safe, frequent, affordable, seamless transportation options that serve your needs. This is the vision of equitable transportation access for all. In this world, transportation is no longer a barrier to accessing job or educational opportunities, medical appointments, recreation, or childcare. This world is made possible by the emergence of new forms of mobility and mobility services coupled with policies and investments in multimodal transportation systems that address decades of underinvestment, systemic racism, and entrenched disparities.

DESIRED OUTCOMES:

- Transportation infrastructure and mobility services are accessible to people with disabilities and low-income households.
- Policies are in place that support multimodal transportation services, including transit, ride sharing, bikes, and scooters, so that people who do not own a car can have a similar level of mobility as people who do.
- Extensive bus lane, bike lane, and sidewalk networks support equitable access and convenient and safe use of efficient and sustainable modes.
- Public transit provides a family of interoperable services and multimodal mobility hubs to connect travelers across modes and enhance access to goods and services.
- New shared mobility technologies are available to safely support a diversity of users and use cases.
- Housing and land-use policy is coordinated with transportation investments to ensure affordable housing is available near transit lines and frequent, reliable, and sustainable mobility services are available in communities with sufficient density.
- Communities have equitable access to sustainable transportation and electric vehicle options and charging infrastructure.
- Data and data analysis methodologies are available to assist transportation planners in assessing equity, job quality, and accessibility issues when making decisions.
- Disparities in the safety, health, job quality, and environmental impacts of transportation activities are eliminated.
- Traffic and transit safety enforcement focuses on risky behaviors and is conducted equitably, justly, consistently, and impartially to eliminate racial disparities in enforcement outcomes.
- Housing and mobility services are in place to allow aging Americans in both urban and rural communities continued access to healthcare and a high quality of life.
- Transportation systems incorporate connected technologies to optimize operations, reduce congestion, and enable convenient multimodal trips.

positioning system (GPS) technologies, including bikesharing, carsharing, ridesourcing, and dynamic ridesharing, to create an array of new mobility options for users. This mobility shift is altering transportation demand, traffic patterns, and consumer expectations, forcing the reconsideration of public transit services, infrastructure designs, and investments. Mobility innovation seeks novel solutions to mobility challenges by using new technologies, improving modeling and simulation tools, and developing driving aids to support mobility for users of all abilities.

Mobility Innovation: Evaluate innovative mobility technologies and services to improve the accessibility, equity, and sustainability of transportation.

- Explore enabling technologies, service models, and policy tools to improve personal mobility for all.
- Develop and test adaptive, inclusive, and assistive transportation technologies that meet the mobility needs of all users.
- Assess the impact of new mobility services on access and barriers to using emerging modes and transportation services.
- Assess the impact of new mobility services on job quality and workplace equity in transportation services.
- Research future public transportation service models and technologies that accelerate the transformation of public transportation providers as integrated mobility managers.
- Research policies, technologies, and business models that have the potential to expand accessibility and mobility services to underserved and disadvantaged communities.
- Explore practices and policies to address transportation insecurity and build mobility resiliency.

Mobility-as-a-Service

Mobility-as-a-Service (MaaS) provides potential users a single integrated channel to access various on-demand passenger travel services. This allows users to access and compare services ranging from micromobility and transit to taxis and vehicle rentals. MaaS aims to provide travelers convenient, sustainable, and affordable alternatives to using private cars. MaaS may support subscription services that enable seamless, ticketless, intermodal trips across a city, region, or country. Ultimately, MaaS could enable municipal and regional government agencies to support policy goals such as sustainability, accessibility, and equity through targeted mobility subsidies.

RESEARCH PRIORITY: WEALTH CREATION

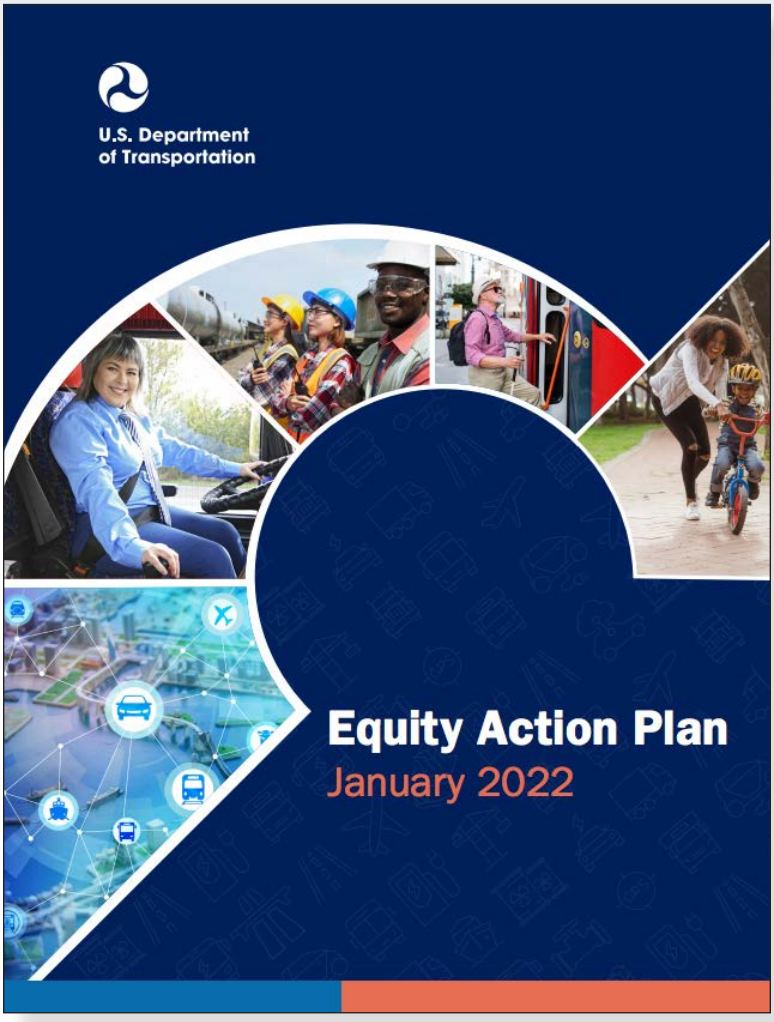
U.S. DOT research funding can create growth opportunities for minority-owned businesses and small disadvantaged businesses. However, restrictive and unclear procurement practices and lack of access to capital and professional networks can make it difficult for these businesses to compete for Federal research contracts. To address these barriers, U.S. DOT is increasing accountability, reducing burdens, and enhancing technical assistance to small disadvantaged businesses. U.S. DOT has set an ambitious goal of increasing research contract dollars that go to small disadvantaged businesses to 20 percent by Fiscal Year 2025, helping these businesses build capital, expand business networks, and attain new skills and experience.

Wealth Creation: Provide technical assistance to small, disadvantaged businesses, Historically Black Colleges and Universities, and Minority Serving Institutions to navigate U.S. DOT research opportunities and the contracting process, gain awareness of upcoming contract opportunities, and enhance their core competencies and skills.

- Create research partnerships with Historically Black Colleges and Universities and Minority Serving Institutions.
- Support domestic small business opportunities and stimulate technological innovation through enhanced use of the U.S. DOT Small Business Innovation Research (SBIR) program.
- Support the development and use of mentorships, internships, and apprenticeship programs designed to increase participation of underrepresented and historically disadvantaged groups in the transportation workforce.
- Create mechanisms that lower the barriers for researchers and entrepreneurs to experiment, partner, and test with potential collaborators, customers and standards development organizations.

U.S. DOT Equity Action Plan

U.S. DOT is undertaking a comprehensive approach to advancing racial equity for all, including individuals who have been historically underserved and adversely affected by persistent poverty or income inequality. The Department's Equity Action Plan identifies actions to improve equity in Federal transportation funding and contracting, support meaningful public involvement in transportation planning and policy decisions, and measure and address transportation access and affordability.



CLIMATE AND SUSTAINABILITY

Climate change presents a significant and growing risk to the safety, effectiveness, equity, and sustainability of the Nation's transportation infrastructure and the communities it serves. Transportation accounts for the largest portion (27 percent) of total U.S. greenhouse gas emissions. As emissions continue to rise, ambitious research and policy efforts are needed to decarbonize the transportation system. The effects of climate change, including rising sea levels and increasing extreme weather, will increasingly put our transportation system at risk from flooding, landslides, wildfires and accelerated deterioration. U.S. DOT's climate and sustainability RD&T efforts aim to substantially reduce transportation-related greenhouse gas emissions and pollution while building more resilient and sustainable transportation systems to benefit and protect communities. Most activities fall into one of four different areas: de-carbonization (including electrification, energy efficiency, and alternative fuels), environmental assessment, environmental mitigation, and resilience.

Table 5. *Climate and Sustainability Research Priorities and Objectives*

RESEARCH PRIORITIES	RESEARCH OBJECTIVES
Decarbonization	• **Electrification:** Conduct research to support expanded access and use of electric-powered transportation and supporting infrastructure to reduce emissions. • **Alternative Fuels:** Advance the development and deployment of alternative fuel technologies. • **Embodied Carbon:** Reduce carbon emissions associated with the extraction and manufacture of construction materials and the construction and maintenance of infrastructure.
Sustainable and Resilient Infrastructure	• **Environmental Analysis and Mitigation:** Develop and promote the use of tools and data to improve understanding of the environmental impacts of transportation projects and activities and to evaluate mitigation strategies. • **Climate Resilience:** Develop and deploy methods to assess and mitigate the risks to transportation system performance posed by climate change.

RESEARCH PRIORITY: DECARBONIZATION

U.S. DOT aims to reduce air pollution and greenhouse gas emissions from transportation and to advance a more sustainable transportation system. RD&T efforts in this area include research on approaches to develop a decarbonization strategy for the transportation sector, incentivize stakeholders in efforts to reduce emissions, and deploy programs to facilitate alternative fuel uptake and operational efficiency.

Electrification: Conduct research to support expanded access and use of electric-powered transportation and support infrastructure to reduce emissions.

- Perform research to guide and support the expansion of vehicle electrification through the designation of charging corridors, and technical assistance, training, and research.
- Develop propulsion technologies that generate less noise, use less fuel, and produce fewer emissions.
- Evaluate strategies to reduce emissions from freight activities including trucks, rail, and at ports.
- Support the development and adoption of low- and zero-emissions vehicles, including trucks and buses, as well as related wireless and fast charging technologies.
- Evaluate the feasibility of building inductive charging capability into highway infrastructure.
- Evaluate the safety of the use of lithium-ion and advanced battery technologies and systems.
- Conduct research and develop best practices for fire and emergency medical services (EMS) responders in interacting with electric vehicle technology and associated infrastructure.
- Evaluate the socio-economic equity of the distribution of environmentally sustainable transportation services, infrastructure, and technologies.

Alternative Fuels: Advance the development and deployment of alternative fuel technologies.

- Perform research to guide and support alternative fuel use through the designation of alternative fuel corridors and technical assistance, training, and research.
- Support the development and deployment of sustainable aviation fuels that reduce noise and emissions while increasing fuel efficiency.
- Build evidence to support the development of standards and inspection procedures to address the safe operation and maintenance of alternative fuel commercial vehicles.
- Assess the safety and performance of hydrogen-fueled or other alternative fuel vehicles, including personal safety for fire and EMS responders.

Joint Office of Energy and Transportation

The Joint Office of Energy and Transportation was established through Title VII of Division J of the BIL (Pub. L. No.117-58) to facilitate collaboration between the U.S. Department of Energy (DOE) and U.S. DOT. This office is aligning resources and expertise across the two departments to address mutually-identified objectives. The office is a critical component in the implementation of BIL. It aims to provide support and expertise to many programs that seek to deploy a network of electric vehicle chargers, zero-emission fueling infrastructure, and zero-emission transit and school buses. The scope of this office will continue to evolve as directed by both departments.

Embodied Carbon: Reduce carbon emissions associated with the extraction and manufacture of construction materials and the construction and maintenance of infrastructure.

- Develop data and methods to assess strategies to reduce the life cycle carbon emissions of infrastructure projects.
- Perform research to support the development of environmental product declarations to communicate the environmental impacts of transportation products.
- Support the development and use of recycled and recyclable materials and products in infrastructure construction.
- Develop and promote the use of lower-carbon materials that meet or exceed the durability and other performance characteristics of competing materials.
- Support the evaluation and/or development of alternative binder technologies with lower embedded carbon than conventional Portland cement.
- Investigate candidate technologies to lower the embedded carbon in asphalt or asphalt-like paving materials.

RESEARCH PRIORITY: SUSTAINABLE AND RESILIENT INFRASTRUCTURE

Through environmental research, the Department seeks to develop innovative approaches that improve the sustainability and resilience of transportation infrastructure. Departmental research seeks to develop tools, models, and approaches that support evidence-based decision-making regarding the environmental impacts of projects. Environmental mitigation RD&T efforts consider how to reduce exposure to hazardous materials, waste, and harmful emissions; deploy natural infrastructure; mitigate noise impacts on communities and ecosystems; and address urban heat island effects. The Department also conducts research to help decision-makers assess and mitigate the vulnerability of transportation infrastructure to climate change, sea-level rise, extreme weather, and natural disasters; identify novel climate adaptation and mitigation strategies; and improve emergency preparedness and response across the transportation sector.

CLIMATE AND SUSTAINABILITY
GRAND CHALLENGE

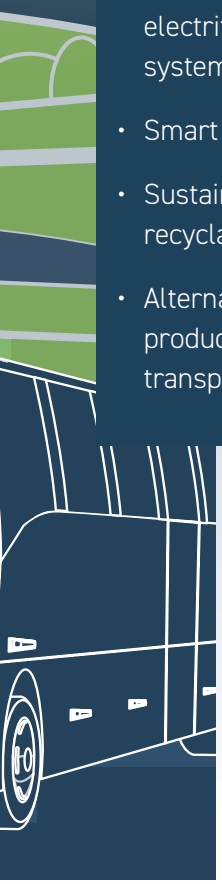
NET-ZERO EMISSIONS

Create a transportation systemthat supports an economy with net-zerogreenhouse gas emissions.

CLIMATE AND SUSTAINABILITY GRAND CHALLENGE

CRITICAL RESEARCH TOPICS:

- Electric vehicle and infrastructure development
- Electric aircraft design and operation
- Battery safety, performance, production, recycling, and disposal
- Rapid charging infrastructure and electrification of road systems
- Smart power grids
- Sustainable and recyclable infrastructure
- Alternative fuel production, storage, and transport



VISION: The transportation sector is responsible for more greenhouse gas emissions than any other sector of the U.S. economy. Dramatically reducing transportation sector greenhouse gas emissions is possible and necessary. Advances in clean energy technology include the development of safe and inexpensive batteries with high storage capacities, efficient and long-lasting hydrogen fuel cells, and advanced technologies for producing low-cost sustainable biofuels. These innovations are ushering in a new age in transportation in which our cars, trucks, trains, planes, and ships will no longer be major sources of air pollution and climate-warming emissions. These advances make it possible to envision a future where the U.S. transportation sector contributes significantly to a net-zero economy.

DESIRED OUTCOMES:

- The vast majority of passenger vehicles and buses are hybrid or fully electric and the efficiency of internal combustion engines is greatly improved. Advances in battery and charging technology make long-range, fast-charging, safe, and affordable electric vehicles the default options for consumers, motor carriers, and transit agencies.
- Charging infrastructure is efficient, affordable, and readily available in all communities.
- Commercial vehicles have become significantly more energy-efficient and the majority rely on electric power or alternative fuels such as hydrogen or biomass fuel.
- Expansion of transit and micromobility services and bicycle and pedestrian infrastructure, combined with integrated transportation and land-use planning, mean that people are less dependent on personal vehicles and more likely to walk, bike, or use transit.
- Expansion of broadband access and advances in virtual technologies mean that more work can be done remotely and people spend less time commuting.
- Fewer personal vehicle trips combined with advances in connected roadway and vehicle technology and operations result in less congestion, improved travel times, less wasted fuel and fewer emissions.
- New aircraft are energy-efficient and use alternative fuels or electric power, reducing the carbon footprint of air travel.
- More frequent and higher-speed intercity rail services mean that travelers are more likely to choose to travel by train for vacations and business travel.
- Thousands of miles of public right-of-way along roadways are repurposed to generate wind and solar energy, or to grow vegetation that stores carbon.
- Transportation infrastructure is increasingly composed of recyclable, recoverable, and durable materials that take less energy to produce, have longer lifecycles, and require less maintenance.
- Marine vessels moving freight or passengers are more energy efficient and/or use alternative fuels and technologies as a method of supporting a carbon-neutral supply chain.

Inductive Charging

Imagine electric vehicles that could charge wirelessly to extend their range and increase their efficiency and convenience. This may be made possible through wireless, in-road charging. Electrification of transit stops, loading docks, and taxi queues could reduce charging downtimes and extend the operating times of managed vehicle fleets, ultimately accelerating the transition away from fossil fuels. Initially deployed for stationary applications, this technology may eventually advance to allow dynamic, in-motion, wireless charging of vehicles on the roadway. Research is needed to develop the technology and operational strategies needed to make this technology cost-competitive with conventional fast-charging technologies and to ensure its safety.

Environmental Analysis and Mitigation: Develop and promote the use of tools and data to improve understanding of the environmental impacts of transportation projects and activities and evaluate mitigation strategies.

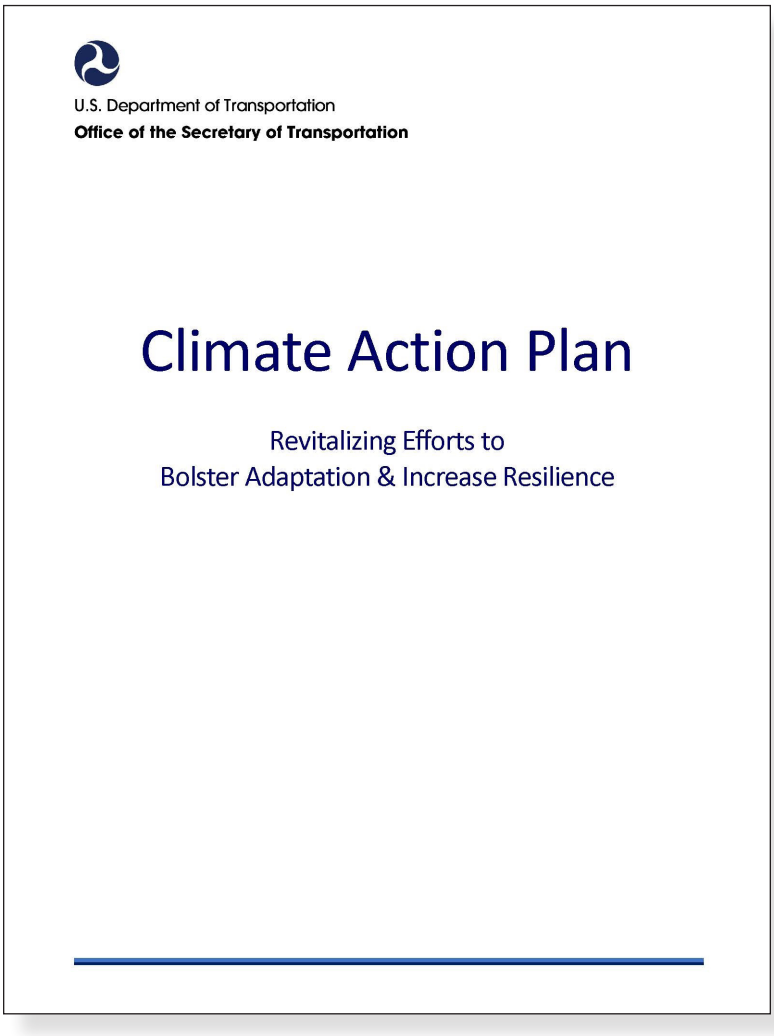
- Develop advanced models for assessing the health and environmental costs of emissions associated with transportation projects and policies.
- Advance the understanding of civil aviation impacts on noise, emissions, health, and welfare.
- Evaluate the health impacts of transportation activities on disadvantaged communities.
- Develop tools to assess the sustainability and lifecycle emissions of transportation policies, projects, and materials.

Climate Resilience: Develop and deploy methods to assess and mitigate the risks to transportation system performance posed by climate change.

- Perform research to identify, develop, and evaluate practices intended to integrate consideration of climate change, sustainability, and resiliency into transportation planning, project development, and design processes.
- Develop risk models and decision-support tools to assess the vulnerability of core assets to extreme weather and sea level rise.
- Develop and deploy tools to assess infrastructure vulnerability and integrate climate resiliency considerations into transportation planning, asset management and maintenance, and project development.
- Drive innovation in geotechnical and hydraulic engineering to improve the resilience of transportation infrastructure to flooding, excessive heat, and other climate impacts.
- Develop and evaluate dynamic, adaptive, and flexible infrastructure technologies capable of efficiently adjusting to changing technology, climate, and traffic conditions.
- Conduct research to develop better financial and risk modeling capabilities to support resilience needs.

U.S. DOT Climate Change Center and Climate Action Plan

The newly established U.S. DOT Climate Change Center will coordinate with Federal agencies to develop a whole-of-government approach to reducing transportation-related emissions. All OAs will produce modal-specific action plans, which will identify clear, feasible actions that each OA will take to reduce emissions and reach key domestic milestones. The U.S. DOT Climate Change Center seeks to use evidence to develop these modal strategies and will continually build evidence to support action plan updates.



TRANSFORMATION

Building a better transportation future will require renewed commitment to purpose-driven, science-based research that puts people first. Through investments in research and education, the Department seeks to foster breakthrough discoveries and to harness emerging technologies that transform the future of mobility, infrastructure, and the broader economy.

Driven by a commitment to experimentation, learning, and innovation, transportation research creates new insights that provide the evidence basis for policy and planning decisions, helps stakeholders evaluate the risks and implications of new technologies, and advances the state of the practice. Public investments in technology research foster American entrepreneurship and job growth by supporting the development of potentially beneficial technologies that are not easily

Table 6. *Transformation Research Priorities and Objectives*

RESEARCH PRIORITIES	RESEARCH OBJECTIVES
Integrated System-of-Systems	• **System Architecture:** Develop technologies and consensus standards to support interoperability, data-sharing, and security across the transportation system-of-systems to produce an integrated multimodal user experience. • **Digital Infrastructure:** Develop the technology, concept of operations, and standards to establish a fully functional, reliable, and secure foundation of transportation system digital infrastructure. • **Connectivity:** Leverage and advance network connectivity and services across transportation systems, infrastructure, cloud and data service providers, and information and communications technology to improve the safety and efficiency of the transportation system, while improving equity and environmental outcomes.
Data-Driven Insight	• **Data Science:** Harness advanced data collection and data processing capabilities to create timely, accurate, credible, and accessible information to support transportation operations and decision-making. • **Strategic Foresight:** Assess, anticipate, and plan for changes to the transportation system.
New and Novel Technologies	• **Automation:** Support the development and responsible deployment of automated technologies that improve the safety, efficiency, equity, and accessibility of transportation. • **Advanced Aviation Systems:** Support the safe integration of emerging aviation technologies and business models into the National Airspace System (NAS).

commercialized, either because returns are uncertain or distant, or because they are difficult to capture. In a transformative and uncertain time, transportation research plays an essential role in developing flexible, adaptive approaches that anticipate and respond to a changing world.

Building a better transportation future will require concerted, coordinated research efforts across and within the public, private, academic, and other sectors. The Department is also committed to strengthening relationships with international research partners to foster collaboration on global issues such as climate change and equitable communities, resilient supply chains, exchanging information on emerging global trends, and providing global leadership on innovative transportation solutions and the development of U.S. and international technical standards. The Department seeks to foster collaboration and competitiveness by working with diverse stakeholders to share information and accelerate the adoption of innovations and emerging technologies. Federal research activities enable information sharing through developing and making accessible new data sets, tools, and standards in partnership with other sectors, as well as by convening diverse stakeholders to listen to varied perspectives, understand needs and challenges, and envision new possibilities. This includes investing in research, education, and training to build skills and create jobs so the workforce is prepared to harness new technologies and practices to create a better transportation future for all.

To achieve our vision of a modern transportation system of the future, Federal research efforts are needed not just to support the development and operation of emerging technologies and systems, such as automation, UAS, and commercial space travel, but to understand the attributes of the desired transportation system of the future along with its risks and capabilities. Transformational RD&T activities focus on creating a people-centered transportation system of the future (see Figure 3).

RESEARCH PRIORITY: INTEGRATED SYSTEM-OF-SYSTEMS

The traditional transportation system we have known since the turn of the 20th century is composed of discrete "domains" that include surface transportation, aviation, maritime, and the emergence of space transportation. Each of these domains is further segmented; for example, surface transportation might include surface vehicles, maritime and rail. Traditionally, each domain has its own set of transportation systems, infrastructure, and operational needs. We are now beginning to see a world where the boundaries between these traditional transportation domains are blurring and blending into a more integrated, holistic, transportation system. Research is needed to support the development and implementation of policies and technologies that will enable an intelligent, safe, interconnected, and people-centered transportation system. In this system-of-systems, individuals and goods can safely, securely, and efficiently travel across modes and jurisdictions.

Figure 3. *Attributes of A Desired Transportation System of the Future*

While advances in technology have transformative potential for the transportation system, Federal leadership in transportation research is needed to ensure the transformation serves the public interest by improving safety and security, supporting economic growth and global competitiveness, increasing equity, and reducing the risks posed by climate change. Key attributes of a better transportation future made possible by the convergence of these technological capabilities include a system-of-systems that is:

People-Centered. Placing humans at the center of the trasportation system with all outcomes oriented to supporting human needs, and public leadership ensuring the deployment of emerging technolgies meets the needs of all people while supporting equitable and inclusive growth and governance.

Safe. Mobility will cease to take human life.

Data Driven. Data serves as the lifeblood of the transportation system-of-systems driving innovation, the development of new business models, and the optimization of system operations and policy decisions.

Intelligent. The responsible use of intelligent technologies to enhance transportation system operations, support transportation workers, and inform data-driven decisions.

Integrated and Interoperable. Modal boundaries dissolve into a holistic, integrated, interoperable ecosystem-of-systems, enabling systems and infrastructure to communicate and coordinate, supporting seamless travel and information sharing across modes, domains, devices, and platforms.

Sustainably Powered. Advances in battery and charging technologies, as well as sustainable fuels and propulsion systems, make clean, low-emission transportation options affordable and attractive, enabling sharp reductions in tranportation-related emissions.

Secure and Resilient. Robust and resilient digital and physical systems are built with defenses, connectivity, redundancy, and flexibility so that they are capable of withstanding and recovering quickly from attack or disruptions.

Adaptive and Dynamic. Transportation systems can detect and adapt to changing conditions, such as changes in traffic demand, advances in technology, or changes to the environment by reconfiguring capacity and adopting new technologies. Future risks are anticiptated, and adaptation strategies are built into the planning, design and operations of infrastructure.

Connected. Pervasive secure and interoperable data and communications connectivity and inter-connected public-benefit services across the transportation system that equitably, affordably, and dramatically improves the transportation experience through improved safety, reliability, and efficiency of the transportation system.

TRANSFORMATION
GRAND CHALLENGE

THE FUTURE TRANSPORTATION SYSTEM-OF-SYSTEMS

Develop connected intelligent infrastructure that provides people-centered mobility.

TRANSFORMATION GRAND CHALLENGE

CRITICAL RESEARCH TOPICS:

- Advanced Materials
- Automation
- Cybersecurity
- Digital System Architecture
- Machine Learning
- Open Data Platforms
- Sensor Technology

VISION: The transportation system of the future will integrate digital technologies and infrastructure to support safe, reliable, and convenient multi-modal travel. This integrated system-of-systems will generate secure and reliable real-time data that drives better decisions by transportation system users, owners, and operators, and supports the development of innovative mobility systems and business models that improve the traveler experience and strengthen the economy.

DESIRED OUTCOMES:

- Sensors, devices, and systems connected by high-speed communications networks produce and consume reliable, secure, trustworthy, real-time data to support decision-making.
- Digital twins, digital infrastructure, and real-time data will improve situational awareness and facilitate management of the national transportation system.
- Connected infrastructure, vehicles, and shared data platforms support cooperative technologies and services, which dramatically improve transportation system safety, operations, efficiency, and maintenance.
- Open data standards and accessible data portals enable shared use of anonymized data to support real-time operations, enhance data analysis and predictive analyses, and enable more responsive, data-driven municipal services.
- Environmental sensors support the assessment and early detection of pollutants, helping public agencies reduce environmental impacts of transportation and respond to environmental emergencies.
- Open access to broadband and wireless services support access to education, employment, health services, and future services enabled by connectivity.
- Transportation systems detect and adapt to changing conditions by reconfiguring capacity and quickly integrating new technologies.
- Established and routinely updated cybersecurity and privacy standards minimize cyber-risks and maintain privacy.
- Construction materials are self-aware, self-healing, and can self-report status.

System Architecture: Develop technologies and consensus standards to support interoperability, data sharing, and security across a transportation system-of-systems to produce an integrated, multimodal user experience.

- Perform research to support the development of a comprehensive national vision for a people-centered transportation system of the future.
- Conduct research to support the development of a reference architecture for a multimodal system of the future that bridges surface, aviation, and space transportation domains.
- Coordinate across government and industry to define a suite of standards, interoperability requirements, and cybersecurity requirements for the transportation system-of-systems.
- Develop the test methods, measures, and testbeds to evaluate and validate interoperability and cybersecurity at the system and system-of-systems levels.
- Perform research to assess the net societal benefit of technologies as they are introduced into the transportation system and over time, as well as their contribution towards the national transportation vision.

Digital Infrastructure: Develop the technology, concept of operations, and standards to establish a fully functional, reliable, and secure foundation of transportation system digital infrastructure.

- Establish a national vision, roadmap, and investment plan for digital infrastructure.
- Conduct research to support the development, implementation, and integration of digital infrastructure to support enhanced transportation safety, efficiency, and connectivity.
- Identify and assess business models and institutional relationships that can ensure long-term sustainability and resilience of digital infrastructure and the underlying standards.
- Support the widespread and equitable deployment of digital infrastructure to optimize automated and cooperative transportation systems and operations and improve connectivity across modes. Conduct research to develop the evidence base needed to support policies, guidance, consensus standards, research, cost-benefit analysis, and test platforms to fully deploy digital infrastructure at a national scale.
- Conduct research to support the development of policies, procedures, guidance, standards, testing, and evaluation of cooperative automation, which enables communication and cooperation between vehicles, infrastructure, and other road users to support driving automation features.

Connectivity: Leverage and advance network connectivity and services across transportation systems, infrastructure, cloud and data service providers, and information and communications technology to improve the safety and efficiency of the transportation system, while improving equity and environmental outcomes.

- Support the equitable and safe rollout of wireless technologies and services, and reliable radio spectrum usage that supports safety-of-life and public safety with spectrum that is free from harmful interference.
- Develop tools and methodologies to support data security, veracity, and validation of connected technologies operating within the transportation ecosystem.
- Conduct research and provide leadership to support the development of standards, architecture, and cybersecurity to support the interoperability and safety performance of inter-connected systems.

Technology Trends Transforming Transportation

Rapidly advancing technology coupled with generational transportation investments have the potential to accelerate the transformation of our transportation system. Some of the primary technology trends that have the potential to transform transportation include:

1) Connectivity & Digital Ecosystem

Information networks will support the integration of the transportation system-of-systems. Whether enabled by 6G, GPS, or advances in radio transmitter technologies, next-generation connectivity will allow networks to move massive amounts of data with extremely low latency and high reliability and flexibility. Connected devices embedded in infrastructure, personal vehicles, trains, ships, trucks, buses, and aircraft will require strategies to address security and privacy.

2) Digitization

The transportation system of the future will leverage massive amounts of data to inform research and development, support decisionmaking, and optimize system operations. Digital twin virtual models of an object or system using real-time data, simulation, and machine learning will aid operational testing and decision-making, and inform and accelerate the design and testing of vehicles, traffic management systems, and air traffic systems.

3) Automation

Technologies that automate operations and control systems are being developed and implemented across every transportation mode including cars and trucks, planes, trains, and ships, as well as at ports, airports, and distribution centers. Automation has the potential to transform safety, mobility, energy, and environmental efficiency, as well as to improve the safety and productivity of the transportation workforce, and facilitate freight movement.

4) Artificial Intelligence (AI) and Machine Learning

AI algorithms that can detect patterns, make sense of their environment, and even learn and evolve, are enhancing our ability to conduct large-scale data analysis, and high-fidelity, high-resolution modeling and simulation to address critical traditional transformation challenges. AI and machine learning have the potential to enhance machine perception, accelerate automation, and improve human-machine interactions.

5) High Performance Computing

The continued evolution of computing power driven by quantum computing, edge computing, and cloud computing are enabling computers to solve massively complex problems at exceptional speed. Exponential improvements in data storage and data processing supported by high-speed connectivity have the potential to transform transportation research and technology and boost connected and automated technologies by enabling real-time decision-making and analytics.

6) Smart Sensors

Advancing sensor technology is a key force underlying developments in intelligent transportation systems, automation, and smart city concepts. The proliferation of smart, connected sensors that can monitor transportation system conditions and performance, as well as related noise and pollution, will provide data to support improved decision-making, and, in some cases, enable the automation of transportation system operations and maintenance.

7) Next Generation Batteries

Low-emissions transportation technologies such as hybrid and all-electric battery vehicles require next-generation batteries featuring safety, high-energy density, long life, and low cost. Researchers are exploring ways to enhance battery performance and safety, slow battery degradation, advance battery manufacturing and recycling capabilities, and advance alternatives to lithium-ion batteries.

8) Advanced Materials

Lightweight, impermeable, recyclable, and self-healing materials now under development have the potential to greatly improve the safety, sustainability, longevity, and resilience of transportation infrastructure. Advances in materials science—from materials for sensors, batteries, and fuel cells to ceramics, lightweight alloys, and high-strength fibers and composites for vehicles and aircraft—are changing what is possible in transportation.

9) Additive Manufacturing

Additive manufacturing, also known as three-dimensional (3D) printing, is the process of building a 3D product by layering materials using a computer-aided design or laser scan. Currently, 3D printers are used to develop prototypes, rare parts, and highly customized products. Applied at scale, industrial-grade 3D printing could alter supply chains as businesses would not need to ship inventory or components long distances, leading to major changes in freight demand and logistics with related impacts to freight congestion and environmental impacts.

RESEARCH PRIORITY: DATA-DRIVEN INSIGHT

The transportation system of the future will incorporate billions of sensors stitched together with an array of technologies and networks, and awash in data. New data sources, tools, and applications have the potential to support more resilient, efficient, and safer transportation systems. Advances in information and communications technologies are enabling more timely collection and analysis of transportation data, allowing for responsive, data-driven decision-making. Research in this area focuses on the development of new sources and types of transportation data as well as tools and models to enable the exchange and analysis of data used to assess safety risks, support investment decisions, improve system operations, and track the long-term performance of the transportation system.

Analyzing and storing massive amounts of new data is a major challenge for transportation stakeholders. U.S. DOT research is developing tools and strategies to enhance transportation stakeholders' capabilities to manage new data sources and analyze highly complex data to achieve new insights. Transportation research plays a critical role in bringing the benefits of new technologies to the public, by collecting data and evaluating experiences to address the effectiveness of emerging technologies, amplify the learning process, and ensuring safe and responsible technology implementation.

Data Science: Harness advanced data collection and data processing capabilities to create timely, accurate, credible, and accessible information to support transportation decision-making.

- Identify the criteria, methods, mechanisms, and responsibilities for the collection, curation, and preservation of research, test, and operational data to be collected by U.S. DOT.
- Conduct exploratory research on transformational mobility data analytics.
- Develop and make accessible data sources, data analysis, and visualization tools to support transportation stakeholders and researchers.
- Establish public-private partnerships to expand access to data on transportation system use and performance.
- Develop advanced, large-scale models, interactive multi-agent models, digital twin technology, and real-time geospatial and sensor data to advance modeling and visualization, transportation system management, and predictive traffic modeling.
- Support the development and integration of open geospatial data to support implementation of emerging technologies to inform research, planning, and policies.
- Develop a U.S. DOT data analysis framework guide for the Foundations for Evidence-Based Policymaking Act of 2018 (the Evidence Act) (Pub. L. No. 115-435) and the U.S. DOT Learning Agenda to ensure research activities include appropriate means to measure outputs and refine research inquiry.

Strategic Foresight: Assess, anticipate, and plan for changes to the transportation system.

- Develop computer-aided decision modeling systems to assess the implications of emerging technologies, forecast travel demand, and assess potential scenarios.
- Support scenario planning and robust decision-making around policy decisions and investments to address future opportunities and disruptions.
- Exchange information on emerging trends with private, public and academic sector peers, domestically and internationally.
- Support research and engagement activities designed to anticipate, respond to, and recover from disruptions.

RESEARCH PRIORITY: NEW AND NOVEL TECHNOLOGIES

The integration of automation technologies across the transportation system has the potential to expand mobility options, improve safety and equity, and drive efficiency and environmental sustainability into the system. The Department's targeted research informs the understanding of new possibilities and how to responsibly integrate them into the existing system. Departmental re-

search includes technology development, analysis, modeling, and simulation tools as well as field tests, pilots, and demonstrations. These activities serve to evaluate the safety and performance of Advanced Driver Assistance Systems and automated driving system-equipped vehicles and assess their impacts on infrastructure, congestion, equity, and the environment.

Collaboration with industry is key to developing cooperative and interoperable technologies and standards that can be deployed to address safety and operational challenges to improve overall system performance. Federal research activities are developing new tools to support the understanding and application of cooperative automation strategies in partnership with a diverse transportation user community. This research spans light duty vehicles, heavy vehicles, transit, intelligent transportation systems, and digital infrastructure.

U.S. DOT research also seeks to understand challenges and opportunities associated with emerging technologies and new business models in aviation. Emerging aviation technologies and applications include the use of UAS, air taxi services, the development of supersonic commercial flight, and commercial space travel. Departmental research in this area will provide the scientific evidence to support the safe operation and effective regulation of new or emerging aerospace vehicles, and safe integration into the National Airspace System.

Automation: Support the development and responsible deployment of automated technologies that improve the safety, efficiency, equity, and accessibility of transportation.

- Conduct research to develop an effective and efficient safety assessment framework for automated systems across all modes of transportation.
- Establish the methodologies, environments, infrastructure, tools and expertise to review, assess and validate the safety of automated transportation systems across all modes of transportation.
- Support the development of a robust, high-fidelity, distributed, affordable, multimodal, collaborative research, test, and evaluation platform for automation technologies.
- Develop best practices for safe interaction of automated roadway vehicles with existing vehicles, roadside hardware, emergency responders, pedestrians, cyclists, and motorcyclists.
- Conduct research to improve the inclusiveness and accessibility of automated vehicle technologies and designs.
- Develop the next generation of roadway infrastructure design and concept of operations to be optimized for digital and automated systems and operations.
- Develop and deploy engineering strategies to integrate the automated surface and low-altitude automated aviation domains for safe, interoperable, and efficient coexistence.
- Conduct research to assess the effects of automation on the transportation workforce, job quality, and workforce training needs.

Advanced Aviation Systems: Support the safe integration of emerging aviation technologies and business models into the National Airspace System (NAS).

- Perform research to inform the development of regulations, policies, procedures, guidance, and standards for UAS operations in the NAS.
- Perform research to support the safe introduction of commercial space in the NAS through improved safety analyses, the development of methods to assess the effect of commercial space travel on the transportation system operation and the public, and the development and deployment of advanced aerospace vehicle safety technologies.
- Support the development and deployment of technologies to improve airspace operation and management capabilities.
- Develop operational requirements and system architecture needed to support advanced air mobility deployment.
- Provide research, data, and analysis to support the development of international standards for subsonic and supersonic aircraft.
- Develop applications of UAS to improve the efficiency and effectiveness of the construction, operation, and maintenance of transportation infrastructure.

Safely Integrating UAS into the NAS

UAS have great potential to expand the reach of transportation services by providing access to locations that may be difficult or unsafe for humans to reach. Once best known for their ability to take aerial photos and videos, new innovations in sensor technology, machine learning, and delivery capabilities have allowed the use of UAS as safe and low-cost tools for transportation activities such as infrastructure inspections, emergency response, construction planning, and other uses. In the near future, the potential applications of UAS include parcel delivery, firefighting, land and crop surveying, and internet access. As UAS rapidly expand in number and complexity, NAS management and operations must evolve as well. FAA's vision for full integration of UAS into the NAS goes beyond simply segregating drones from other aircraft. It involves UAS operating harmoniously alongside crewed aircraft and applying many of the same air traffic management procedures in place for conventional aircraft. FAA is exploring expansion of crewed and uncrewed vehicles flying cargo and passengers hundreds of feet above populated areas and developing a concept of operations for operations above 60,000 feet.

Putting People First - Smart Cities and Communities

The Department has released the Putting People First – Smart Cities and Communities report. The report summarizes the benefits, goals, challenges, and success factors associated with smart cities and communities and gives a glimpse of the path forward. The report describes three hallmarks of smart cities and communities: 1) they use networks of sensors to gather and integrate data that can be used for various applications and to support citizen services; 2) they use connectivity to enable officials to interact directly with the community and better monitor and manage city infrastructure; and 3) they are committed to an open data philosophy and routinely share operations and planning data with the public.

TECHNOLOGY TRANSFER AND DEPLOYMENT

CHAPTER 3

Our world is healthier, smarter, more connected, and more sustainable because of the U.S. taxpayer's investment in discovery and innovation that has supported the commercialization of new products and services. Federal funding for research and development (R&D) is essential to maximizing the benefits of science and technology to tackle the climate crisis and to advance health, prosperity, security, environmental quality, equity, and justice for all Americans. As stated by the White House Office of Science and Technology:

"Federal agencies should ensure that the R&D results are made widely available to other scientists, to the public to facilitate understanding and decisions, and to innovators and entrepreneurs who can translate them into the businesses and products that will improve all of our lives. And, as we seek to make our supply chains more resilient, R&D investments should create more than just cutting-edge technology; they should also create products that are made in the United States by U.S. workers."

— Executive Office of the President, Multi-Agency Research and Development Priorities for the FY 2023 Budget

The Department is committed to effective technology transfer (T2) by identifying high potential research products and technologies across the Department and working with Federal and non-Federal stakeholders to accelerate successful technology commercialization and deployment across the nation. The Department is committed to delivering its R&D results to people who will put it to use for the benefit of the country.

U.S. DOT researchers work closely with current and potential users of research products in the public and private sectors to accelerate T2 and deployment. U.S. DOT research includes activities such as evaluating the performance of new technologies and identifying and assessing best practices and lessons learned from the application of innovations in the field. This research helps stakeholders make informed decisions about whether to adopt new technologies, policies, or practices. To further encourage the adoption of innovations, U.S. DOT agencies publish technical papers and guides; present webinars and deliver presentations to stakeholders; create websites; develop and deliver training courses and workshops; engage in standards development activities, and distribute newsletters and other outreach materials highlighting research results. U.S. DOT agencies also work closely with stakeholders throughout research projects to

understand research needs, develop and pilot practical solutions, promote the adoption of these solutions, and evaluate their use and effectiveness. Within U.S. DOT, agencies use a wide range of methods to support the deployment of technologies and innovations, including pilot and demonstration projects, grants for pilots and early adopters, challenge grants, technical assistance, and peer exchanges.

The Department's technology transfer efforts are critical to translating transportation research into outcomes that make transportation better for people. By getting data, tools, and skills into the hands of transportation officials, entrepreneurs, and other stakeholders, technology transfer drives improvements to our transportation system and spurs economic growth. By advancing ideas, making them public, and moving them into the marketplace, the Department's T2 Program advances the deployment of people-centered technology solutions that make our transportation system safer, more efficient, more equitable, and more sustainable.

TECHNOLOGY TRANSFER PROGRAM

Secretary Buttigieg has emphasized the central role that transportation innovation and transformation must play in "winning the 21st Century." Congress has stated its support for this goal in the BIL, which created 49 U.S.C. §6504, requiring the Department to ensure that research investments result in changes to regulations or practice. This Congressional direction aligns with the Biden-Harris Administration's policy priority to accelerate the transition of discoveries quickly from the lab to the marketplace and ensure that new technologies and products developed with support from the United States Government are manufactured in the United States, whenever feasible.

The vision for the Department's T2 program is to advance the economic, transportation, and national security interests of the nation through partnerships with diverse innovators to accelerate the commercialization and deployment of beneficial transportation technologies.

The priorities of the U.S. DOT T2 program are to:

1) Launch research and technology programs whose outcome is targeted to technology transfer from the beginning of the project;

2) Ensure research investments are fully leveraged through the demonstration and deployment of the resulting products and technologies;

3) Accelerate technology commercialization and deployment of transportation innovations;

4) Identify leading-edge transportation technologies or products that could be manufactured in the United States; and

5) Advance coordinated interagency approaches to innovation and research solicitations with the goal of reducing barriers to program participation, streamlining access to funding opportunities, and encouraging production of new technologies in the United States.

The program will ensure that DOT's R&D capabilities and innovations help the United States win the 21st Century and strengthen its role as the global leader for transportation science and technology. In particular, the DOT T2 program will support the maturation and deployment of DOT's innovations, providing ongoing safety, mobility, equity, economic, climate, and security benefits for all Americans.

Section 25016 of BIL (49 U.S.C. §6504) requires the Department to conduct a review of U.S. DOT research and identify modifications to laws, regulations, guidance, and other policy documents to incorporate any innovations that have the potential to improve the safety or efficiency of the U.S. transportation system (see Table 7). To meet this requirement, the T2 Program is working with modal partners to identify research that has demonstrable benefits to the transportation system that may require any statutory or regulatory modifications for adoption.

Partnering with Industry on Technology Deployment: Fuel Cell Bus Longevity Study

"Fuel cell bus technology ready for widespread commercialization"

Project Name: Alameda County, California Transit Fuel Cell Bus Longevity Study

In July 2020, the FTA published its report on the Alameda County, California (AC) Transit Fuel Cell Bus Longevity Study, conducted by the Center for Transportation and the Environment (CTE). CTE monitored 13 fuel cell electric buses (FCEBs) as a part of the FTA's National Fuel Cell Bus Program (NFCBP), working with AC Transit, UTC Power, EnerDel, Van Hool, Siemens Industries, and Dynetek Industries in this endeavor.

The extended monitoring demonstrated the exceptional durability of this technology, as the buses were still exceeding their expected performance nine years after they entered service. The data show that these buses are durable and reliable and met or exceeded many of the performance targets identified by FTA and the U.S. DOE for determining the readiness of the technology for widespread commercialization. Deployment of FCEBs instead of diesel buses will reduce emissions and reduce operational costs long-term.

AC Transit's Hydrogen Fuel Cell Buses

Over the term of this plan, the T2 program hopes to better position itself as the clearinghouse for all DOT products, laboratories, and expertise by strengthening the following activities:

Table 7. *T2 Priorities and Objectives*

T2 PRIORITIES	2022-2026 OBJECTIVES
Ensure research investments are fully leveraged through the demonstration and deployment of the resulting products and technologies	• **Research Planning:** Require that T2 performance measures be incorporated into research project lifecycle planning at an early stage. • **Early-Stage Identification:** In partnership with the modes, identify potential research and lab efforts ripe for demonstration. • **AMRP Linkage:** Ensure that the deployment opportunities are connected with AMRPs.
Accelerate technology commercialization and deployment of transportation innovations	• **Technology Coordination:** Develop a centralized function to institute structured channels to commercialize transportation innovations. • **Communicate Successes:** Continually improve mechanisms to share promising research, outcomes of demonstration projects, and available patents and licenses for scalability. • **Investor Outreach:** Host investor/T2 events to raise awareness of viable technologies. • **Process Improvement:** Create processes that align statutory requirements with Federal public access and open science mandates to increase research uses.
Identify leading-edge transportation technologies or products that could be manufactured in the United States	• **Domestic technology scans:** Identify U.S. government-funded technologies and products that are market-ready for domestic commercialization and deployment. • **Encourage Domestic Production:** Work with stakeholders to initiate and expand U.S production pipelines for technology efforts.
Advance coordinated interagency approaches to innovation and research solicitations with the goal of reducing barriers to program participation and streamlining access to funding opportunities	• **Partnership Development:** Create novel, cross-agency approaches to solicitations that meet multi-agency goals and outcomes. • **Expanded Outreach:** Continue to engage communities, partners, and consort on upcoming opportunities.

U.S. DOT TECHNOLOGY TRANSFER AND DEPLOYMENT ACTIVITIES

U.S. DOT's Operating Administrations fund a wide variety of laboratories, programs and partnerships that support the Department's T2 mission.

U.S. DOT FEDERAL LABORATORIES

The goal of T2 is to share information and technologies among Federal laboratories, private industry, and academia as well as to share resources such as personnel, facilities, methods, expertise, and technical information. U.S. DOT research centers include:

- FAA – William J. Hughes Technical Center
- FAA – Civil Aerospace Medical Institute
- FHWA – Turner-Fairbank Highway Research Center
- FRA – Transportation Technology Center
- NHTSA – Vehicle Research and Test Center
- Office of the Secretary of Transportation – Volpe National Transportation Systems Center

U.S. DOT's research centers coordinate with more than 300 Federal laboratories around the nation to make T2 processes accessible and to support successful commercialization of Federal research products.

UNIVERSITY TRANSPORTATION CENTERS (UTC)

To advance the state-of-the-art in transportation research and technology and develop the next generation of transportation professionals, the U.S. DOT's UTC Program awards and administers grants to consortia of colleges and universities across the U.S., including at Historically Black Colleges and Universities and other Minority Serving Institutions, and at community colleges. The mission of the UTC Program is to advance U.S. technology and expertise in the many disciplines comprising transportation through education, research and T2 at university-based centers of excellence. The UTC Program seeks to advance T2 by making transportation research results available to potential users in a form that can be commercialized or otherwise deployed. U.S. DOT encourages unique approaches to research, education, workforce development, and T2 to build on and reflect institutional expertise, facilities, and partnerships. To achieve its vision of a truly multimodal integrated system, U.S. DOT encourages UTCs to engage in research, education, and workforce development, as well as T2 activities that cut across disciplines and span multiple modes of transportation. These activities aim to support improvements to the Nation's surface transportation system, including rail, maritime, highway, pipeline, transit, and links to aviation.

SMALL BUSINESS INNOVATION RESEARCH PROGRAM (SBIR)

U.S. DOT is one of 11 Federal agencies that participates in the SBIR program. U.S. DOT's highly competitive SBIR program awards contracts to domestic small businesses to pursue research on, and develop innovative solutions to, our Nation's transportation challenges. The U.S. DOT SBIR program favors research that has the potential for commercialization through products and applications sold to the private sector transportation industry, State departments of transportation, U.S. DOT, or other Federal agencies.

Small businesses that participate in U.S. DOT's SBIR program have developed numerous new and innovative technologies that have benefited the Department and the public, while providing a basis for growth for small businesses. Over the past five years, the U.S. DOT SBIR program has invested $50 million in qualified small businesses.

EVERY DAY COUNTS

Through the Every Day Counts program, FHWA works closely with States to identify and rapidly deploy proven, yet underutilized innovations that make our transportation system adaptable, sustainable, equitable and safer for all. Proven innovations promoted through Every Day Counts facilitate greater efficiency at the State, Local and Tribal and territorial levels, saving time, money and resources to ensure our infrastructure is built better, faster, and smarter. FHWA works with State transportation departments, local governments, Tribes, private industry and other stakeholders to identify a new collection of innovations to champion every two years that merit accelerated deployment. Many of these innovations have become mainstream practices across the country. By advancing 21st century solutions, the transportation community is making every day count to ensure our roads and bridges are built better, faster, safer, and smarter.

BIL INNOVATION PROGRAMS

Innovation-focused activity enabled by the BIL will include a range of approaches across transportation modes in communities throughout the country. This work relies on the strength and creativity of many stakeholders, including State, local, Tribal and territorial governments; universities, community colleges, and research laboratories; and industry partners, such as small businesses and entrepreneurs.

Key innovation programs authorized under the BIL include:

- **Strengthening Mobility and Revolutionizing Transportation (SMART) Grants** – A new competitive grant program that supports State, local, and Tribal governments in conducting demonstration projects to advance smart city or community technologies and systems that improve transportation efficiency and safety, as well as other priority goals such as climate

mitigation, resilience, and equity. The Department anticipates that the SMART grant program will include two phases. The first phase will support planning, team-building, and developing a proof-of-concept; the second phase will include demonstration projects at greater scale.

- **Advanced Transportation Technologies and Innovative Mobility Deployment** – A competitive grant program available to State and local governments and agencies, metropolitan planning organizations, regional partnerships, and research consortia for the development of advanced transportation technologies and innovative mobility deployments.
- **Advanced Research Projects Agency-Infrastructure (ARPA-I)** – A new agency within U.S. DOT modeled after the Department of Defense's Defense Advanced Research Projects Agency and DOE's Advanced Research Projects Agency-Energy, ARPA-I's mission is to catalyze the development of innovative technologies, systems, and capabilities that transform the nation's physical and digital infrastructure to ensure American leadership. We aim to build the future of transportation that is safe, secure, efficient and resilient, while achieving net-zero emissions and increasing equity and access for all. ARPA-I will support advanced research and deployment, innovative partnerships, and T2 activities across sectors.
- **Open Research Initiative** – A new advanced transportation research pilot program that supports States, local governments, universities, nonprofit organizations, and private sector organizations by enabling them to submit unsolicited research proposals addressing unmet U.S. DOT research needs.
- **Nontraditional and Emerging Transportation Technology (NETT) Council** – Established in law to identify and resolve jurisdictional and regulatory gaps associated with nontraditional or emerging transportation technologies, including issues related to safety, environmental review, and funding and financing.
- **Smart Community Resource Center** – An online resource, established by U.S. DOT in partnership with other Federal agencies, on intelligent transportation system and smart communities approaches for use by State, local, Tribal and territorial governments.
- **Transportation Resilience and Adaptation Centers of Excellence (TRACE) Grant Program** – A competitive research and development grant program that supports institutes of higher education to improve resilience to natural disasters and extreme weather by promoting the resilience of surface transportation infrastructure. The TRACE grant program supports ten regional Centers of Excellence and one national Center of Excellence.
- **Department-wide research funding** – The BIL provides more than $5 billion in research funding to support research efforts including T2 across the Department. The Department's OAs support various research and grant programs focused on professional capacity building, pilot and demonstration projects, and research partnerships designed to accelerate technology commercialization and deployment in the field.

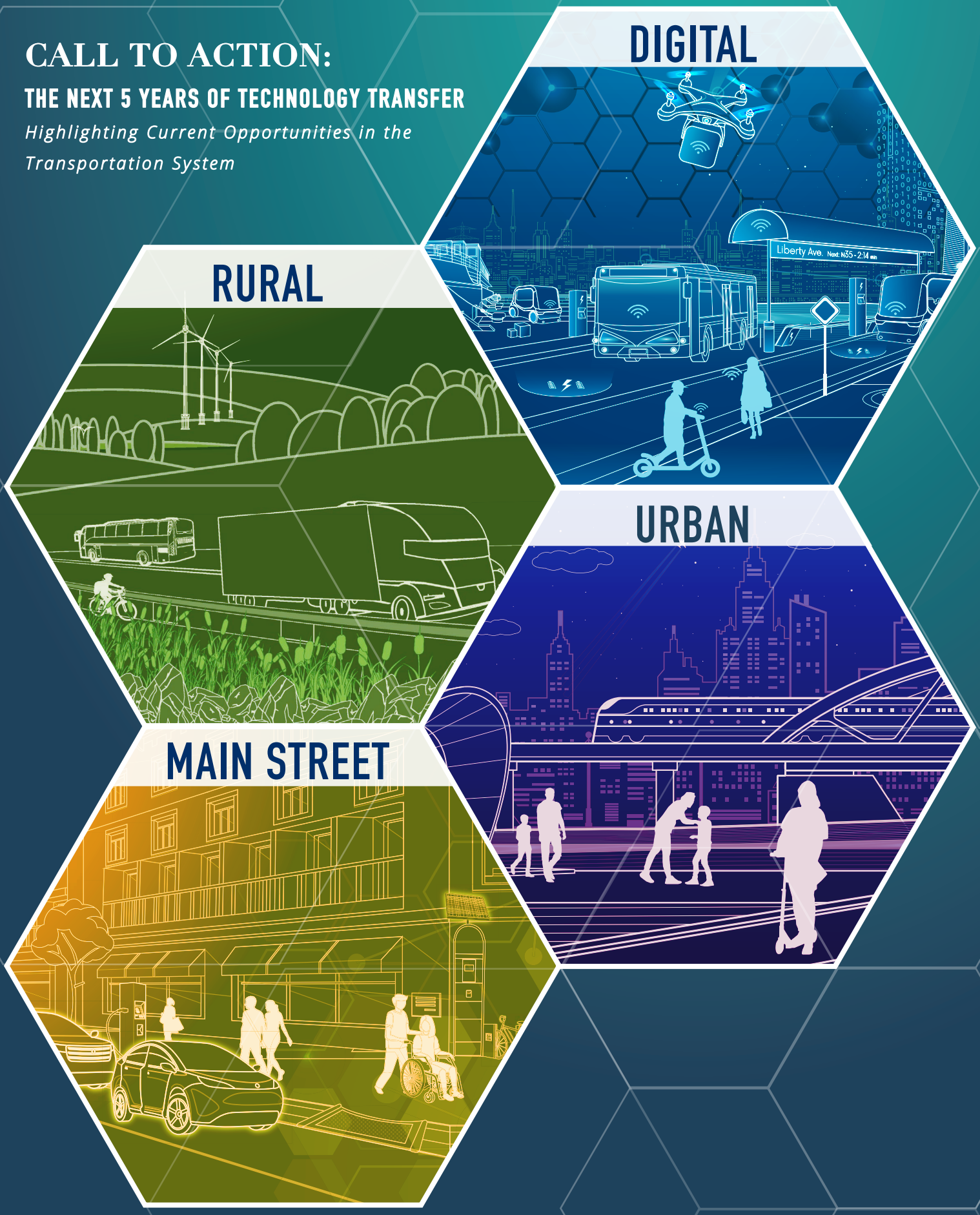
The BIL includes numerous programs to support technology pilots and deployments that will accelerate the transformation of our transportation system through the implementation of emerging technologies and best practices. These purpose-driven investments will support the application of data and technology to solve challenges like potholes, pollution, and parking, and to make communities more sustainable, equitable, and livable.

Executing on our technology transfer priorities requires an accounting of the present-day opportunities for innovation across the transportation system. The following graphics highlight a set of opportunities to leverage data, technology, and new approaches to make our system safer, more efficient, more sustainable, and more equitable. This illustrative list highlights the types of real-life challenges that can be addressed across sectors, by infrastructure owners and operators, entrepreneurs, industry, academics, and more.

CALL TO ACTION:

THE NEXT 5 YEARS OF TECHNOLOGY TRANSFER

Highlighting Current Opportunities in the Transportation System



DIGITAL – ILLUSTRATIVE TECHNOLOGY TRANSFER APPLICATIONS

ADVANCING DATA TOOLS AND TECHNOLOGY TO IMPROVE OPERATIONAL EFFICIENCY, COLLABORATION AND PUBLIC ENGAGEMENT

Data Sharing systems and processes that collect, share, and integrate transportation, housing, and health data across agencies.

Digital Public Engagement tools that support equitable community engagement in infrastructure planning and delivery.

Simulation Tools to model the transportation system to optimize traffic flow and consider priorities like pedestrian movement, accessibility, and school routes.

Modeling tools for planning and infrastructure decisions like housing, transit-oriented development, and economic development.

Open Data protocols and systems that enable data-driven integration by asset owners, transportation operators, and community organizations.

Resilient Connectivity to support current and future transportation needs.

RURAL – ILLUSTRATIVE TECHNOLOGY TRANSFER APPLICATIONS

INNOVATIVE APPROACHES TO MAKE RURAL TRANSPORTATION SAFER AND MORE SUSTAINABLE

Uncrewed Aircraft Systems for delivery of medical supplies or emergency medical equipment to improve emergency response and post-crash care in remote areas.

Automated Crash Attenuators to improve the safety and efficiency of highway maintenance activities.

Trucking Parking Information Systems to enable on-demand reservation services to improve truck driver safety, security, and quality-of-life.

Roadway Friction Data Collection to systemically identify potential high friction surface treatment installations to reduce roadway departure crashes.

Carbon Sinks in highway right-of-way for carbon mitigation and preservation of natural habitat can help to remove carbon, improve noise pollution and air quality, and reduce risk of flooding and erosion.

Renewable Energy Generation on highway right-of-way to add generation capacity and support transportation-oriented microgrids.

MAIN STREET – ILLUSTRATIVE TECHNOLOGY TRANSFER APPLICATIONS

MULTIMODAL TECHNOLOGY SOLUTIONS TO IMPROVE SAFETY, EQUITY, AND SUSTAINABILITY

E-cargo Bike Delivery to reduce emissions and curbside congestion associated with last-mile delivery.

Mode-Agnostic Mobility Accounts to get people where they need to go without the need to own or operate a car.

Dynamic Use of Curb Space enabled by open data standards for freight deliveries, passenger pick-up and drop-off, transit, and parking.

Sensor Technologies mounted on multipurpose datahub pole attachments, including environmental sensors for air quality and lidar to support safe travel by non-motorized users.

Micro-Charging Stations for e-bikes and e-scooters to improve usability, reduce operational costs, and spur economic development.

Automated Enforcement deployed equitably and applied appropriately to roads with the greatest risk of harm due to speeding, can provide significant safety benefits and save lives.

Adaptable Smart Infrastructure to facilitate on-demand conversion of right-of-way for pedestrians and cyclists and after-school play zones.

URBAN – ILLUSTRATIVE TECHNOLOGY TRANSFER APPLICATIONS

SMART SOLUTIONS TO MAKE CITIES CLEANER, SAFER, AND MORE EFFICIENT

Demand-Responsive Transit Routing that aligns service provision with real-time system demand, commute patterns, events, and traffic patterns.

Off-Peak Electric Charging using parking facilities and public space to charge transit, e-mobility, and freight fleets.

Chemical Sensors to detect hazardous materials, gas leaks, or other unsafe conditions, along with integrated response systems.

Accessibility Data Collection using standardized metrics that allow for integration with mapping and routing services and help prioritize infrastructure redesign and repair.

Environmental and Infrastructure Condition Mapping to facilitate non-car commute patterns prioritized for safety, air quality, temperature, and light.

Dynamic Traffic Management Systems that respond to non-recurring congestion related to crashes, events, street closures, and weather.

Traffic Signalization Systems that integrate with transit and emergency vehicle routing to improve service and decrease response times, reduce conflicts, and alleviate congestion.

IMPLEMENTATION

CHAPTER 4

Implementation of this *RD&T Strategic Plan* will take place on two levels. First, there are several statutory requirements that establish how this plan will be used to guide and report the Department's RD&T activities over the next five years. Second, OST-R will execute its U.S. DOT RD&T portfolio review mandate through an established RD&T Review and Approval Process that is based around the development and review of AMRPs. Through this process, OST-R will provide guidance and partner with the OAs to scope projects that maintain high levels of performance and cost-effectiveness.

STATUTORY REQUIREMENTS

OST-R is charged by Congress with proactive coordination, facilitation, and review of U.S. DOT's multimodal research portfolio. The implementation of this *RD&T Strategic Plan* is designed to build on the statutory requirements described in 49 U.S.C. Chapter 65 (Research Planning) and in Table 8 below.

Table 8. *Statutory Requirements under 49 U.S.C. Chapter 65 (Research Planning)*

(Section 6503 covers the statutory requirements for this five-year *RD&T Strategic Plan*.)

SECTION	TITLE	DESCRIPTION	HEADING
§ 6501	Annual Modal Research Plans	A comprehensive overview of OAs' research plans for the upcoming fiscal year and a detailed outlook for the following fiscal year. AMRPs should advance the goals and research priorities of the DOT *RD&T Strategic Plan*.	(a)
§ 6502	Consolidated Research Database	A comprehensive public-facing database of all research projects conducted by U.S. DOT, including a description of research objectives, multimodal applications, funding levels, and findings and outcomes produced upon project completion.	(a)
	Funding Report	A report containing details of the amount spent by the Department in the prior fiscal year on RD&T activities and the amount proposed in the President's Budget Request for the next fiscal year.	(b)
	Performance Plans and Reports	A summary of the Department's RD&T activities for the previous fiscal year in each topic area; amount spent in each area; a description of the extent to which the RD&T activities are meeting expectations as presented in the *RD&T Strategic Plan*; and any amendments made to the *RD&T Strategic Plan*.	(c)
§ 6504	Incorporation of U.S. DOT research	A review of the Department's research in concurrence with the *RD&T Strategic Plan*. Identify research results, e.g., innovative practices or technologies that have demonstrable benefits, such as improving the safety or efficiency of the Nation's transportation system. Determine if the results require certain modifications for adoption, propose modifications and a description as to how the results will be incorporated into the Department as part of the Technology Transfer Program.	(a), (b), (c)

RD&T REVIEW AND APPROVAL PROCESS

U.S. DOT has established a research review process to ensure that the Department's research portfolio advances the goals and priorities of this *RD&T Strategic Plan*. OST-R is responsible for executing the review process as part of its statutory review mandate. AMRPs prepared by the OAs and joint program office are used for the review in conjunction with project plans submitted by each agency prior to the commencement of the fiscal year. Biannual briefings from the OAs and joint program office to OST-R are conducted to review progress made on research plan implementation and to discuss plans for the upcoming fiscal year.

Key components of the review process include identifying potential opportunities for collaboration between or among the OAs; identifying and eliminating any projects that are duplicative or unnecessary; and identifying ways to improve the implementation of research findings, such that the outputs and outcomes of the research portfolio benefit the safety, mobility, and efficiency of the Nation's multimodal transportation system while also facilitating positive economic and societal impacts, including impacts related to climate change and equity. Structuring the review around these three tiers — *RD&T Strategic Plan*, AMRPs, and project plans —ensures continuity and consistency in meeting U.S.DOT's research planning, coordination, review, and reporting responsibilities.

EVALUATION

Evaluation of RD&T activities provides the basis for understanding the impacts of those activities and any efforts to update Departmental processes designed to ensure impacts from RD&T. As such, evaluation is essential to the effective management of the Department's RD&T portfolio. The Evidence Act established government-wide activities that seek to build evidence that supports policymaking. Each Cabinet agency designates senior staff to coordinate evidence-building activities and advise on statistical policies and procedures. The U.S. DOT Learning Agenda, a key part of evidence-building activities, documents priority questions aligned with the Department's Strategic Goals and outlines potential data, tools, methods, and analytic approaches to be used to answer priority questions. U.S. DOT conducts research and evaluation activities in support of that Learning Agenda.

It is useful to consider three steps in establishing effective evaluation practices at the Department. First, it is necessary to define desired outcomes at every organizational level at which outcomes are tracked. This is possible by aligning statutory mandates listed in Table 8 that are maintained at different levels, in particular the *U.S. DOT Strategic Plan*, the *RD&T Strategic Plan*, the AMRPs, and the modal projects reported in the Consolidated Research Database, Funding Report, and Annual Performance Plan and Report. Processes to ensure this alignment are described later in this document.

Second, key performance indicators (KPI) that measure the extent to which intended outcomes are achieved must be defined. In support of BIL, U.S. DOT is integrating ambitious new KPIs to ensure that our research aligns with Departmental strategic goals, as noted in Table 9.

Table 9. *Transformation Key Performance Indicators*

STRATEGIC OBJECTIVE	KEY PERFORMANCE INDICATOR
Matching research and policy to advance breakthroughs: Foster breakthrough discoveries and new knowledge through high-risk, high-reward research driven by policy objectives.	Double the number of research and deployment projects centered on breakthrough discoveries that introduce new technologies or approaches not currently deployed in the transportation system.
Experimentation: Identify new ideas, new innovations, and new possibilities. Evaluate the opportunities and risks so the Department can support public benefits.	By 2026, support 25 novel data and technology approaches related to artificial intelligence, cybersecurity, and infrastructure resilience in communities across the U.S.
Collaboration and Competitiveness: Work with diverse stakeholders to share noteworthy practices and accelerate the adoption of worthwhile technologies.	By 2026, create a digital forum to engage 10,000 transportation professionals to share best practices and use cases on smart cities and communities, technology, and data in transportation.
Flexibility and Adaptability: Design flexibility into transportation system investments to accommodate and respond to changing needs and capabilities to provide long-term benefits.	By 2026, support 25 projects that build data and technology systems for transportation planning and infrastructure operation that serve as interoperable platforms that can engage with various tools, technologies, and approaches.

To evaluate progress made on its T2 activities, the Department tracks the use of research results by U.S. DOT stakeholders using metrics such as downloads of U.S. DOT technical reports, U.S. DOT research leading to patents of new technologies, and technology implementations. The Department's T2 KPIs include:

- # of Collaborative Research and Development Agreements (current)
- # of Patents and Copyrights (current)
- # of Technology Transfer License Agreements (current)
- # of contracts awarded through SBIR (current)
- # of Success Stories (Evidence of Societal Benefits) (current)
- # of Funded Agreements with Deployment Demonstrations (new).

These KPIs, and others, are reported on in the Department's Technology Transfer Annual Summary Report.

Third, evaluation plans must be developed and implemented, based on defined KPIs and other metrics. Evaluation plans consider the full lifecycle of a research project or T2 activity and define approaches to understand the level of success of each step in that cycle. This generally involves considering inputs, activities, outputs, outcomes, and impacts using quantitative and qualitative analysis. This rich analysis provides the basis for recommendations to improve RD&T management processes, as well as estimating the benefits of investments in a particular RD&T program or project. Evaluation results will inform the report on Incorporation of U.S. DOT Research mandated by 49 U.S.C. 6504, to help identify modifications to laws, regulations, guidance, and other policy documents that incorporate U.S. DOT research and have the potential to improve the safety or efficiency of the U.S. transportation system.

Table 10 provides examples of measurable research elements (inputs, activities, outputs, and outcomes) that agencies can track to support the evaluation of DOT-sponsored RD&T efforts. The first row presents examples of the inputs, activities, outputs, and outcomes for a research program, while the second row presents examples for a T2 program that supports research deployment. The third row shows example components of an evaluation program, but it should be noted that a comprehensive evaluation will require data from both research development and deployment. Additional terminology useful for defining, tracking, and evaluating the results of DOT research and T2 activities is defined in the Glossary.

Table 10. *Logic Model for Research Development and Deployment*

	INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES
R&D Development	• Legislation • Funding • Technical expertise • Collaborative partnerships • Lab facilities • R&D baseline data • Stakeholder engagement	• Stakeholder analysis • Content development • Methods development • Experimentation • Data collection • Analysis • Technology testing • Development coordination • Evaluation coordination	• Inventions • Hardware • Software • Processes • Methods • Publications • Data, databases • Copyrights • Patent filings	• Improved knowledge • Improved processes • Invention value added • Project goals met, as measured by evaluation (e.g., improved safety)
T2 Deployment	• Review of relevant T2 cases • Plan for deployment funding • Gather T2 baseline data • Continuous stakeholder engagement	• T2 plan development, including user and champion identification • T2 outreach materials development • Securing deployment funds and support • Training • Deployment coordination • Evaluation coordination	• Publications • Newsletters • Briefs • Website downloads • Outreach events • Demonstrations • Licenses • Success stories • Voluntary consensus standards	• Increased user awareness and knowledge (measured by citations, downloads, licenses, success stories, etc.) • Increased usage (measured by interview, surveys, tracking systems, royalties, etc.) • Project goals met, as measured by evaluation (e.g., improved safety)
Evaluation	• Evaluation planning • Evaluation funding • Selection of evaluators	• Development of evaluation materials • Baseline data analysis • Further data collection (e.g., statistics, interviews) • Data analysis	• Findings and recommendations • Presentations • Briefings • Webinars • Internal and external reports	• Improved knowledge • Programs adopt recommendations to improve future processes and outcomes • Programs actively include evaluation on future projects

CONCLUSION

CHAPTER 5

U.S. DOT is committed to building a better transportation future for all Americans. Federal transportation research is fueling the innovation necessary to improve transportation safety, strengthen the U.S. economy, address the climate crisis, and create a more equitable, affordable, and accessible transportation system for all Americans.

In this time of rapid change, innovation, and experimentation, research must drive the learning necessary for the actions taken by the public sector to keep pace with technological advancement and to adapt to evolving needs. Research provides policymakers with the tools and information to purposefully and proactively transform our transportation system to create a better future for all.

Transforming the transportation system will require collaboration across all levels of government, academia, and industry, starting with sound, coordinated research. American leadership in transportation research will position the transportation industry to meet rapidly shifting demands and compete in an era of globalization.

That leadership starts with a transformative vision of a people-centered transportation system that provides safe, accessible, reliable, and sustainable transportation for all through purpose-driven research and innovation for this and future generations. In this people-centered vision, the needs of people drive the purpose of research efforts rather than the development of technology for its own sake. This people-centered perspective and sense of purpose drives our national transportation research vision.

Working together, we can build a better transportation future for all.

APPENDICES

ACRONYMS

3D . . . . . Three-dimensional
AI . . . . . Artificial Intelligence
AMRP . . . . . Annual Modal Research Plans
ARPA-I . . . . . Advanced Research Projects Agency-Infrastructure
BIL. . . . . Bipartisan Infrastructure Law
DOE . . . . . Department of Energy
EMS . . . . . Emergency Medical Services
FAA . . . . . Federal Aviation Administration
FHWA . . . . . Federal Highway Administration
FMCSA . . . . . Federal Motor Carrier Safety Administration
FTA . . . . . Federal Transit Administration
GPS . . . . . Global Positioning System
ITS JPO . . . . . Intelligent Transportation Systems Joint Program Office
KPI . . . . . Key Performance Indicator
MaaS . . . . . Mobility as a Service
MARAD . . . . . Maritime Administration
NAS . . . . . National Airspace System
NETT . . . . . Nontraditional and Emerging Transportation Technology
NHTSA . . . . . National Highway Traffic Safety Administration
NIST. . . . . National Institute of Standards and Technology
NRSS . . . . . National Roadway Safety Strategy
OA . . . . . Operating Administration
OST-R . . . . . Office of the Assistant Secretary for Research and Technology
PHMSA . . . . . Pipeline and Hazardous Materials Safety Administration
R&D . . . . . Research and Development
RD&T . . . . . Research, Development, and Technology
PNT . . . . . Positioning, Navigation, and Timing
SBIR. . . . . Small Business Innovation Research
SMART . . . . . Strengthening Mobility and Revolutionizing Transportation
TRACE . . . . . Transportation Resilience and Adaptation Centers of Excellence
T2 . . . . . Technology Transfer
UAS . . . . . Uncrewed Aircraft System
U.S. DOT . . . . . United States Department of Transportation
UTC . . . . . University Transportation Center

GLOSSARY

Activities: What the program does with allocated resources. Activities are the processes, events, and actions that are an intentional part of the program implementation. These interventions are used to bring about the intended program changes or results.

Advanced Research: Advanced technology development that creates new technology or demonstrates the viability of applying existing technology to new products and processes in a general way. A study that achieves transformational change rather than incremental advances.

Applied research: Applied research is defined as original investigation undertaken in order to acquire new knowledge. Applied research is, however, directed primarily towards a specific practical aim or objective.

Basic research: Basic research is defined as experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts. Basic research may include activities with broad or general applications in mind, but should exclude research directed towards a specific application or requirement.

Demonstration: A demonstration, or demonstration project, is an information exchange mechanism intended to show, explain, or prove the value of an innovation in a context where that innovation is new or unfamiliar. It allows hands-on experiences for participants who interact with knowledgeable peers and others experienced in the technology application. A demonstration is similar to a showcase.

Deployment: Deployment of an innovation is the transformation of that innovation from a packaged, limited use to an operational state with broad usage. Deployment may include opening, arranging, installing, testing, or otherwise preparing an innovation for full, intended usage. The result of deployment is that the innovation is ready for implementation.

Development: Development is defined creative and systematic work, drawing on knowledge gained from research and practical experience, which is directed at producing new products or processes or improving existing products or processes.

Evaluation: A systematic study using research methods to collect and analyze data to assess how well a program is working, and why. Evaluations answer specific questions about program performance and may focus on assessing program operations or results. Evaluation results may be used to assess a program's effectiveness, identify how to improve performance, or guide resource allocation.

Impact: The long-term impact of an outcome on the transportation system, or society in general, such as reduced fatalities, decreased capital or operating costs, beneficial community impacts, or environmental benefits.

Innovation: Something new or improved, having marketable potential, that includes the development of new technology, the refinement of existing technology, or the development of new applications for existing technology.

The Long-Term Effect: Implementation of an innovation is the complete execution of a plan or process to put that innovation into full effect. The result of implementation is that the innovation is fully employed by end users.

Outputs: The results of work performed under R&D activities. The outputs could include processes and methods; data, hardware, software and databases; invention disclosures, patent filings, inventions, etc.

Outcome: Progress toward achieving the intended result of a program. Indicates changes in conditions that the Government is trying to influence.

Portfolio: A strategically structured, organized grouping of programs, activities, resources, or other efforts through which coordination and coherence in implementation enables the achievement of agency goals and objectives. Agencies will group programs and associated activities into a portfolio in a manner that will best enable effective management and oversight of the portfolio.

Program: An ongoing initiative composed of a group of projects and other work managed in a coordinated way to obtain benefits not obtained from managing them individually.

Project: A temporary endeavor to create a unique product or service with a start date, a completion date, and a defined scope.

Research: Research is creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of people, culture, and society—and to devise new applications using available knowledge.

Technical Assistance: Activities that are technical in nature, undertaken to help others achieve a desired outcome. In the context of technology implementation, technical assistance will typically take the form of expert guidance, hands-on training and/or advice.

Technology Deployment: Activities that demonstrate, pilot, or evaluate an R&D output, and/or facilitate the transfer of an R&D output to an adoption-ready state. Technology deployment is the final phase of the T2 process.

Technology Transfer: The process by which existing knowledge, facilities, or capabilities developed under Federal R&D funding are utilized to fulfill public and private needs.

U.S. Department of Transportation