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NSF Engineering Research Visioning Alliance

Sustainable Transportation Networks

Visioning Event Report

Courtesy of Colorado State University Walter Scott, Jr. College of Engineering

Executive Summary

Transportation benefits individuals, businesses, and communities by moving people, goods, and services across town and around the world. Transporting people or freight is also the largest user of energy in developed countries and the most rapidly growing energy user in developing nations. Future engineering research must address the need for sustainable mobility modes and the infrastructure, both physical *and* digital, that underpins transportation networks.

Future transportation networks and modes will embrace efficient energy usage, produce low or no emissions, use alternative construction materials and novel construction and manufacturing processes, enhance the efficiency of freight and logistics, and employ appropriate levels of automation and connectivity. Such was the consensus of participants at a recent visioning event coordinated by the Engineering Research Visioning Alliance (ERVA) to identify roles for the engineering research community in achieving sustainable transportation networks.

Three high-level themes emerged from the event as broad research principles:

- Improve and leverage data-informed operations in transportation systems.
- Advance sustainable technologies that incorporate versatile materials for use in devices, infrastructure, and energy supply chains.
- Improve equity and accessibility for humans through better design of mobility devices and services.

Research in these areas must emphasize a range of attributes—safety, affordability, resilience, diversity, equity, inclusion, and accessibility in mobility—to drive the positive impacts on social and economic conditions that will improve all communities. *Engineering can lead essential research efforts to accelerate solutions for the complex problems inherent in creating sustainable, equitable transportation systems.*

Given the broad nature of the theme, this report is not intended to be an exhaustive exploration of potential research directions for sustainable transportation networks. The event's Thematic Task Force, comprised of academic, corporate, and nonprofit experts, narrowed the scope of the visioning event to focus on less-explored research directions and identified four topics within the theme to consider in depth:

- **Infrastructure:** Present and future transportation infrastructure materials, networks, construction techniques, and evolving requirements.
- **Vehicles and Transportation Modes:** Current and future vehicles and modes of transportation that emphasize reliability, sustainability, and safety without sacrificing environmental and economic benefits.
- **Data:** Data collection and use to enable transportation networks to function more efficiently and safely while protecting individuals' privacy.
- **Our People and Community:** Ways in which current and future systemic engineering practices can foster equitable and just access to transportation networks.

The participants leveraged their combined expertise and identified 12 "big ideas" within these four topic areas to prioritize for engineering research investment to advance progress toward more sustainable, equitable transportation systems. Those priorities are listed below and are explored more fully in this report.

Identified Research Priorities in Brief

Infrastructure

1. Develop sensors and data-informed algorithms to permit self-diagnosing, healing, and adaptive infrastructure and that are affordable, scalable, and functional in all elements of transportation systems;
2. Investigate modeling to explore digital twins and how they can assist in increasingly complex planning, predicting in-service performance under extreme demand scenarios, and understanding of the interactions of transportation, climate, economic, and other systems; and
3. Conduct materials research to develop construction materials and methodologies to increase the sustainability, adaptability and resiliency of transportation infrastructure components.

Vehicles and Transportation Modes

4. Build batteries, charging infrastructure, and power grids that are more efficient and affordable for all modes of electric vehicles;
5. Advance informatics, data science, and civil infrastructures to enable communication systems that aid in the transition from mobility assets (vehicle ownership) to a mobility services (shared rides/mass transit/micromobility) model;
6. Enhance all aspects of freight transport, including fuels, vehicles, infrastructure, and operations management; and
7. Improve sustainability of the air transportation system by
   - learning more about condensation trails (contrails) and their environmental impact, and
   - enhancing navigation patterns and efficiency to minimize the carbon footprint of the system.

Data

8. Implement enhanced data modeling capable of recognizing and accounting for bias to create safe, robust, equitable, and accessible transportation systems;
9. Rethink and redesign how data is collected, managed, and shared across the engineering spectrum; and
10. Develop adaptive artificial intelligence (AI) systems that can account for both human decision-making and other external/contextual elements.

Our People and Community

11. Leverage expertise in mechanical, materials, computer, and electrical engineering, along with urban planning, to explore the concept of self-sustaining community microgrids that democratize accessibility; and
12. Design safe, sustainable transportation models that leverage and respond to the local needs and capacities of each community, with community feedback loops and research engagement.

Courtesy of Louisiana State University College of Engineering

"Bold thinking lays the foundation for us to stay at the forefront of engineering and technology by identifying tomorrow's ideas and fostering transformational engineering research."

CATHY CHOI

ERVA Thematic Task Force co-chair and executive director, Cummins Inc.

Courtesy of Clemson University International Center for Automotive Research (CU-ICAR)

Taking Action

The idea of **improved and integrated data-informed design, construction, and operations** explicitly or tacitly underpins every research priority discussed at this event. In our interconnected society, data is collected, stored, managed, and analyzed at every point in a transportation event, whether it is an individual driving on an interstate highway or buying a mass transit ticket to cross a city. From encrypted sensors to secure storage, and from algorithms that can account for context in real-time decision-making, to predictive analytics that understand the bias built into legacy transportation priorities, data-informed systems of the future will incorporate the best of machine logic and human input to help build, maintain, and continuously improve transportation systems on all levels.

Sustainable transportation systems cannot be built or maintained by relying on unsustainable materials or processes. Engineering research on **sustainable materials** for infrastructure, for vehicles—from personal mobility to mass and freight transit on land, sea, and air—and for energy supply chains, particularly zero emissions technologies, is critical to create a system that is attainable and sustainable through construction and life cycle. Whether systems rely on biomimicry to build adaptable roads, power capturing surfaces on homes, vehicles, and in the community to resupply community microgrids, swappable battery/zero carbon fuel systems that alleviate the need for charging, or alternative fuel stations in rural areas, engineering practical and affordable solutions to small- and large-scale problems is key to truly sustainable transportation networks.

These transportation networks should be equally accessible to all. Because legacy systems often displace people or do not adequately provide access, creating sustainable and equitable systems is a weighty and interdisciplinary challenge for researchers. The engineering research community can, however, significantly contribute to improved mobility by designing vehicles and systems that are inclusive of the entire range of users. By designing for equity at all levels, from infrastructure to transportation mode, engineers will work toward the goal of sustainable transportation networks that improve quality of life for all.

Given transportation's central role in society, boldly re-envisioning how all modes can benefit current and future generations is a compelling priority. Engineering-led research will take a central role in shifting transportation from an obstacle to negotiate to a quality-of-life-enhancing experience. And it must do so in ways that are efficient, affordable, and safe. This report aims to inspire researchers and funders (public, private, and nonprofit) to support and pursue these engineering research priorities.

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Visioning Alliance

Our mission is to identify and develop bold and transformative new engineering research directions and to catalyze the engineering community's pursuit of innovative, high-impact research that benefits society.

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