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TOWARD SAFER ROADS AND RAILS

Pathway to the Next Level of Transportation Safety

by Tony Colavito

OCTOBER 2023

Across the globe, billions of devices are producing immense volumes of data, exchanging it in real time with each other and the broader environment as part of a collaborative ecosystem.

This digital revolution provides the surface transportation industry with an unprecedented opportunity to take safety to a whole new level.

Our transportation infrastructure is already communicating with vehicles on our roadways, such as traffic lights that change to green as an ambulance approaches. The "connected vehicle," which exchanges data wirelessly with both infrastructure and other vehicles, is also becoming a reality. And across the transportation spectrum, vehicles are being equipped with automated safety features.

These vehicles are generating vast amounts of telemetry data—everything from diagnostic codes to information about operator behavior. The number of vehicles equipped to capture this kind of data is growing rapidly. And as the number of connected devices grows, the number of potential interactions grows exponentially.

Evolving Safety in the Digital Age

While automated safety features and connected vehicles hold great promise, they also introduce challenges. For instance, traditional safety approaches—such as those that look at a linear progression of events to determine the cause of a safety incident—may be difficult to apply effectively in an interconnected world.

> **The changes in the transportation environment facilitate new approaches to safety, where hazards are identified and mitigated *before* they manifest into accidents.**

MITRE proposes a way forward, drawing on expertise gained as the operator of the Federal Aviation Administration's (FAA) federal R&D center for 60 years and a partner to the U.S. Department of Transportation (DOT) and transportation stakeholders on numerous initiatives.

Four Principles for the Next Level of Safety

We have identified four areas of opportunity that provide a roadmap to the "Next Level of Safety" across the transportation spectrum. These areas include: a system-of-systems approach, proactive monitoring and analysis, the sharing of safety information across stakeholders, and smart policies focused on safety outcomes.

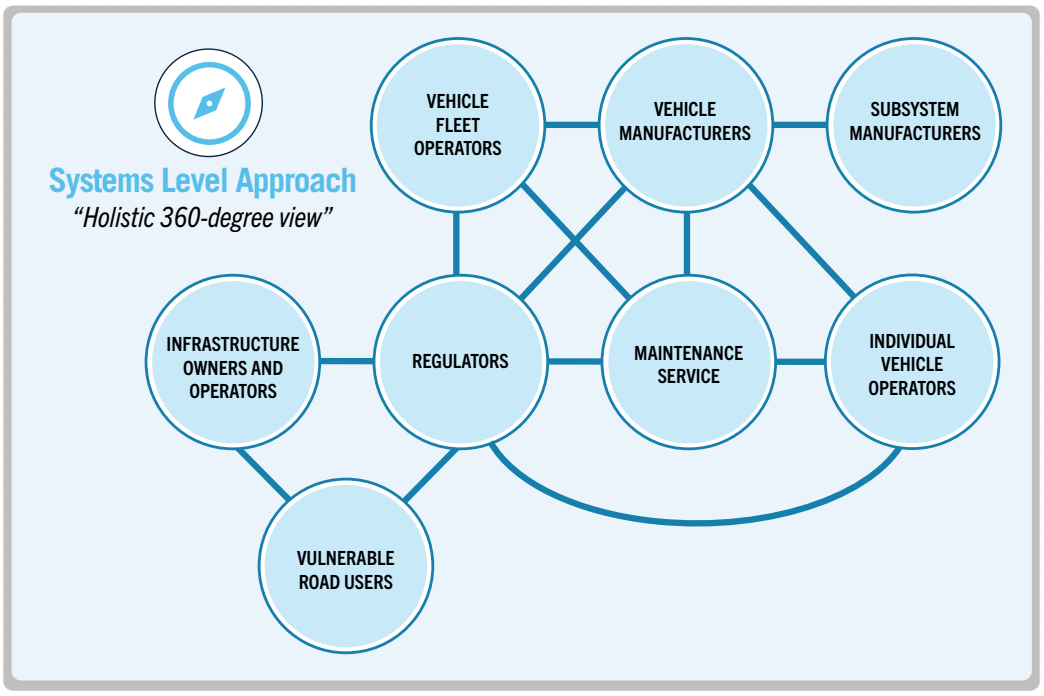
1 Systems Level Approach: Gaining a Holistic 360-degree View

All modes of transportation are systems of systems in that they are enabled by interdependent components that work together to provide a service. Transportation safety in any mode is a byproduct of the risks inherent in each component, as well as risks arising from their interaction. In fact, research indicates that the predominant cause of accidents in some transportation sectors is lack of information exchange between the organizations responsible for managing safety.

With these facts in mind, the Next Level of Safety calls for a system level approach, which requires certain shifts in thinking and action to achieve.

First, the entire system (people, process, and technology) must be accounted for when considering safety, including the increasing role of human-machine teams.

Adopting a system-of-systems perspective encourages a shared, comprehensive understanding of the environment, gained in part through proactive risk management. Safety must be built into the span of potential human-machine teams applied in transportation, such as operating a vehicle, optimizing fleet efficiency, and managing traffic throughput.



Additionally, safety management systems (SMS) must shift from the traditional single-organization focus to a 360-degree safety review that incorporates all stakeholders. This allows multiple organizations to analyze and manage their common risks, share discoveries before accidents or incidents occur, and understand the effectiveness of mitigations.

By applying these principles, the community will be able to discover better solutions faster than any one organization operating independently. If multiple organizations work together to monitor leading indicators, the opportunity to spot new issues before they create significant risk is increased.

System level safety management helps identify hazards that exist when integrating operations among organizations.

The vast potential of the data that these organizations collect lies in accessing and augmenting it with advanced technologies, such as networked sensors, edge processing, wireless connectivity, cloud computing, and machine learning. These technologies and techniques can provide a more holistic view of safety by acquiring data from a range of sensors at the system edge, transmitting that data in near-real time and integrating it with other datasets in a cloud environment, and then building models upon that pooled data to generate novel insights or real-time interventions.

In the future, much of the cross-organizational sharing will move beyond raw data to include AI-generated insights about trends and anomalies into leading indicators of safety issues like emerging hazards. These analytical insights can lead to a holistic understanding of safety that is descriptive (what happened?), diagnostic (why did it happen?),

Ports: A Holistic View

The nation's ports are a microcosm of the kinds of diverse stakeholder engagements that occur in the transportation domain. Local, state, and national regulatory bodies are involved in the oversight of port operations. Trucking companies use these locations to drop off and receive cargo, and ships carrying both people and goods are frequent users of these national entry points.

As we invest in improved infrastructure for these critical hubs in our supply chain, a question we must ask is: How do we safely introduce changes and coordinate them among all affected parties? Without such coordination, the interests of some parties may be emphasized while those of others are overlooked, introducing unacceptable safety risk.

predictive (what will happen?), or prescriptive (what action should we take?). The organizations can then work together to improve the depth of the analysis and determine the best solution.

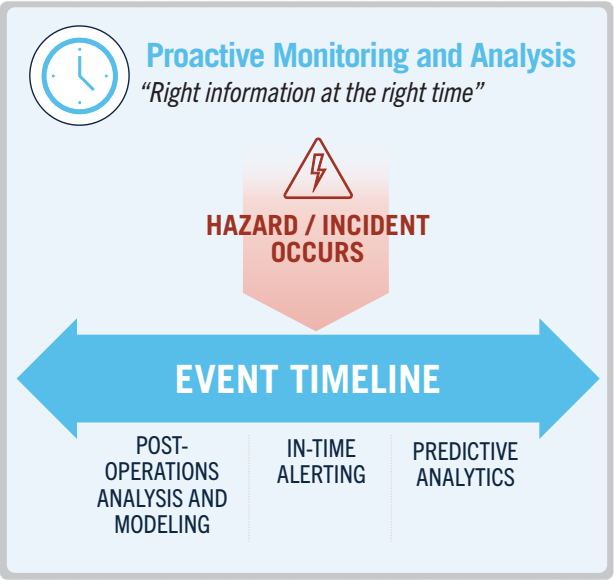
In addition, holistic safety performance measures can inform the organizations' collective strategic safety priorities, government activities, and the public's perception of safety.

Rail Safety: Bringing Perspectives Together

All seven major U.S. freight railroad operators, as well as other short-line and passenger rail companies, solicit rail safety concerns from their employees via formal programs and, in 2023, they agreed to participate in a similar national program called the Confidential Close Call Reporting System.

To advance rail safety beyond employee reporting, the rail community must view safety holistically, learning and collaborating across organizations.

The Federal Railroad Administration (FRA) sought to demonstrate the potential value of this approach through a large-scale "data trust"—a shared, confidential database managed by a trusted third party to analyze rail operations data—when it piloted the Railroad Information Sharing Environment (RISE) in 2018. To realize that program's potential, FRA needs to sustain its commitment to the program and secure broader participation.



2 Proactive Monitoring and Analysis: Delivering the Right Information at the Right Time

Today's data-rich environment is enabling the shift from a reactive to a proactive and predictive safety approach. Proactive monitoring and analysis that employs advanced technologies can detect anomalous events and emerging hazards, provide insights and predictions, and allow for appropriate actions to be taken before they manifest as accidents or incidents.

When applying the Next Level of Safety principles, stakeholders combine a network of fused operational, systems, and environmental data with artificial intelligence/machine learning (AI/ML)-based technologies to generate timely safety intelligence in both strategic and tactical timeframes. Human decision makers and autonomous systems working together as a team use this information to automatically monitor system performance, understand operational impacts, and identify unanticipated system interactions.

Long-range forecasts of accident risk inform strategic safety investment priorities. Near-term forecasts provide tactical support to operational actions, such as maintenance priorities and staffing levels.

MITRE is working to create a virtual representation of the transportation system to test the capabilities of new vehicle technologies—and their interactions with system users—before deployment. This sort of capability will be vital as automakers introduce increasingly automated safety features on their vehicles, and as the transportation environment becomes increasingly complex.

A Proactive Approach: VOICES

The Virtual Open Innovation Collaborative Environment for Safety (VOICES) partnership is a voluntary, user-centered, multi-sector start-up collaboration between industry, academia, and government that is enhancing interoperability of research and testing tools, environments, and systems to improve surface transportation technologies.

Together, innovators from technology development firms and suppliers, original equipment manufacturers, and research institutions within government and academia are finding new ways to break down silos, safely and easily share information and data, and identify solutions that will accelerate crucial innovation in transportation safety.

* *Co-developed by industry, academic, and government leaders within the VOICES Community, funded by the US Department of Transportation, and operationally supported by MITRE*

3 Data Democratization: Incentivizing Data and Information Sharing

A key element of the Next Level of Safety is "data democratization," or ensuring that data and information are accessible to as many stakeholders as possible. Shared data enables stakeholders to produce more robust predictive analyses and safety intelligence insights, coordinate their mitigations, and understand how to recover from unforeseen hazards.

> **To maximize the benefits of a systems perspective, members of the community must be incentivized to share safety data, from local to global levels.**

As a foundational step, issues related to data security, governance, trust, and standards need to be addressed. For example, a set of common frameworks and data standards would facilitate the broad adoption of interoperable solutions and accelerate the impact of data sharing.

Advancements in Transit: Data Standards

A first step in data democratization is establishing industry standards on how to define operations, design features, infrastructure, and safety incidents so that organizations speak a common language. In the transit sector, the Federal Transit Administration (FTA) manages mandatory safety reports for rail transit incidents, including their causal factors, in a standard format using the National Transit Database.

Further, the American Public Transportation Association works with FTA and transit operators to establish voluntary standards for bus transit systems, rail transit systems, and technology for transit systems. Individual transit operators are also developing taxonomies to inform their safety risk management processes.

The next step for the transit industry is to develop and apply a standard taxonomy to address safety hazards that may or may not have resulted in an accident or incident, providing a foundation for proactive and predictive hazard mitigation as well as sharing and analysis across transit operators.

Government regulators can serve as a catalyst in fostering information sharing among industry stakeholders. This includes sharing insights from regulatory monitoring activities as feedback to assure the effectiveness of safety controls. Objective third parties can assist in building trust between government and industry stakeholders. For example:

- The Partnership for Analytics Research in Traffic Safety (PARTS)—a public-private partnership through which the National Highway Traffic Safety Administration (NHTSA) and automobile manufacturers share safety data with MITRE for analysis—is helping to advance traffic safety.
- The Aviation Safety Information Analysis and Sharing (ASIAS) program—a data-sharing partnership between industry, the FAA, and MITRE—has helped to dramatically improve safety in the airline industry.

Shared Data: Advancements under PARTS

As the PARTS partnership and dataset expand, researchers are studying increasingly nuanced and emerging research questions. For example, a recent first-of-its-kind, cross-industry study examined the real-world effectiveness of advanced driver assistance systems (ADAS) in passenger vehicles. Eight automakers provided vehicle equipment data for 47 recent model year vehicles, and NHTSA provided 12 million crash reports from 13 states. By fusing those data sources, researchers were able to obtain a clearer understanding of ADAS effectiveness than would have been possible using a single entity's data.

4 Smart Policy: A Focus on Safety Outcomes

The final principle that will elevate the transportation ecosystem to the Next Level of Safety is smart policy. Because traditional safety regulatory approaches are often a poor fit for today's increasingly dynamic and complex digital environment, government regulatory policy is also shifting. Common elements of success include policy that:

- is performance-based and focused on safety outcomes, promoting industry self-discovery, disclosure, and correction;
- enables innovation by granting industry flexibility on how to achieve the desired safety outcomes while providing regulators with controls to protect against corruption and other associated risks; and
- empowers all organizations to provide oversight in a "shared mission" operational chain (i.e., manufacturers, maintenance organizations, operators, and regulators).

Adoption of a "safety continuum" is an example of this approach. Not all trucking operations, for instance, need to be held to the same requirements to maintain consistent safety outcomes. Federal and state regulations differ based on vehicle weight, the type of freight being carried, and the extent of the route. This same "continuum" approach could be applied to other aspects of transportation as well. Ideally, a safety continuum would align regulator and industry safety management goals with the public's safety level expectations, while also granting industry innovation flexibility.

At an operational level, regulators would use oversight to promote greater shared understanding of the system level operational environment, potential risks, and associated impacts among stakeholders, in addition to determining regulatory compliance.

Oversight attention would be focused on the shared discovery of risks and better coordinating the layers of mitigation across stakeholder organizations.

Smart Policy: Safety Focus During a Disaster

In a disaster, a functional transportation system is the backbone for evacuation, search and rescue, and the delivery of emergency services and supplies to the devastated region. With natural disasters increasing in intensity and attacks on infrastructure becoming a greater threat, there is a continued need for policy that builds in mechanisms for a nimble, coordinated response.

Shared data, analyses, collaboration, and smart policy are all critical components to effectively address these questions:

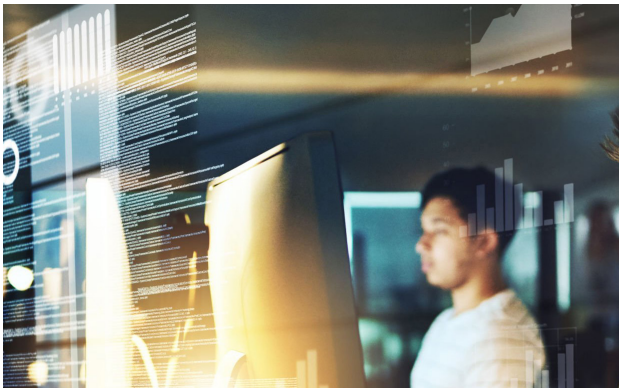
- If key roadways are unavailable as evacuation routes, how can stakeholders coordinate to provide evacuation via rail or air?
- If railways typically used to transport supplies are damaged, what is the Plan B for rerouting supplies to get them to people quickly?
- How do we strategically invest in our transportation system so that these multimodal strategies exist ahead of time and can be executed as needed?
- What communication structures and processes should be enabled in advance so that real-time coordination will be possible during a crisis?

Moving Forward as a Community

To achieve this vision, members of the transportation safety community must come together and accelerate implementation of the Next Level of Safety principles. MITRE recommends these next steps for moving forward:

- To advance a **systems level approach**, transportation operators, vehicle manufacturers, parts suppliers, maintenance providers, and regulators should fully adopt and implement SMS and move toward system level SMS by sharing both safety data and findings with each other. The U.S. aviation industry has successfully implemented SMS among commercial airlines via FAA regulation over the past 15 years and is presently expanding the requirement for airports. Over the past 5 years, federal regulations that emphasize implementation of safety risk management processes require the U.S. transit and rail communities to follow suit. There is also an opportunity for transportation community members to jointly develop a transportation vision, centered on safety, that they all see themselves in and an actionable roadmap for achieving that vision through safety investments and collaborative programs.

- To advance **proactive monitoring and analysis**, transportation regulators, infrastructure owners and operators, fleet operators, vehicle manufacturers, and maintenance organizations should continue to connect with each other to facilitate data sharing and generate timely safety intelligence. A whole-of-nation perspective across the transportation ecosystem should be leveraged to advance the science of AI/ML technologies in support of short- and long-term safety forecasting. As fleet operators continue to increase safety data collection and analyses, governments should invest in mechanisms to manage and analyze data and share leading practices—to support community-collected, data-driven insights and better regulations.
- To advance **data democratization**, transportation regulators, infrastructure owners and operators, fleet operators, vehicle manufacturers, and maintenance organizations should develop and promote a set of common frameworks and data standards, while addressing data security and governance issues. By sharing data and insights from regulatory monitoring activities, governments can model the behavior that supports this principle. There is also an opportunity for governments to establish regulatory protections so that transportation operators and suppliers are comfortable voluntarily submitting safety information. Some individual programs provide protections against punishment for employee safety reports, but the transportation community needs broader protections for all safety data, including for civil liability if the organization makes a good faith effort to identify and mitigate hazards.



- To advance **smart policy**, governments should continue to pursue a uniform safety continuum approach that aligns safety management goals with the public's safety level expectations. To lay the groundwork for safe transportation, the U.S. government has outlined policies that emphasize connected intelligent infrastructure and provide people-centered mobility. More specifically, this presents an opportunity for the transportation community to collaborate on digital infrastructure to accelerate adoption of connected and automated vehicles and realize the associated safety benefits.

Conclusion

The digital revolution is transforming the surface transportation environment by creating more connectedness than ever before between systems and human users. Understanding the safety implications of this greater connectivity requires broad community understanding and engagement with a more diverse set of users to generate new safety insights.

By taking a systems perspective, sharing data, proactively monitoring and identifying risks, and implementing smart policy, we can create safer roads and rails.

About the Author

Tony Colavito is a senior principal systems engineer at MITRE focusing on road and rail transportation safety. He leads a research portfolio at MITRE advancing a seamless, intelligent, and equitable U.S. transportation system of systems. Colavito earned a B.S. degree in systems engineering from the University of Virginia and an M.S. in engineering management from The George Washington University.

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