Future Directions for Transportation Safety Research

The key to the ongoing challenge for safer transportation is continued research to develop and apply innovative technologies and operations, to increase our understanding of operator behavior and accident causes, and to identify any safety issues associated with emerging technical and societal trends.

Greater transportation safety is a continuing challenge. The success seen since the creation of the Department of Transportation has been impressive. The Volpe Center has been an important part of that story, not only in addressing mode-specific challenges but also in exploiting synergy across modes. However, the growth in population and transportation activities necessitates an ongoing endeavor to prevent an increase in casualties. It is even more difficult to accelerate the downward trend in accident rates and reduce the overall toll. Technical and societal changes exacerbate some current problems and introduce new ones. There may be unanticipated adverse safety impacts associated with the relatively rapid introduction of new structures, materials, vehicle technologies, propulsion systems, and operational practices. The highly competitive global economy will put increased pressure on transportation service providers—pressures that could reduce their will or ability to maintain a total commitment to safety. Shifts in the mix of vehicles in the national fleet could pose a variety of safety challenges.

This issue of the Volpe Journal includes many examples of proven approaches that should continue. However, the new challenges, as well as an apparent leveling off of the rate of improvement, make it necessary to augment and revitalize traditional approaches by taking full advantage of recent and emerging technological advances. Many opportunities now exist that can contribute significantly to preventing accidents, mitigating consequences, and improving responses to incidents in all modes.

Two parallel and interrelated areas offer particularly promising results:

1. **Technology.** Digital/information technology (sensing, communications, automation, data processing, navigation, etc.) and innovation in vehicle materials, structures, and propulsion systems will play a major role in safety improvements.
2. **Human performance and behavior.** Improved understanding of human performance and behavior, including the interaction of people with technology changes, will be critical in fully exploiting the promising opportunities for reduction in the human and system failures that contribute to the accident toll.

The discussion emphasizes highway safety, which represents well over 90 percent of transportation-related deaths and injuries. However, the approaches discussed are directly relevant to all modes and represent topics in which the Volpe Center's thorough understanding of safety, technical expertise, experience in working with academia and the private sector, and broad system perspective will enable the Center to continue its long history of significant contributions to transportation safety.

TECHNOLOGY

Technological change contributes to transportation safety in four arenas:

1. **Technological Operator Aids.** Electronic and automated systems that prevent crashes by reducing the likelihood and magnitude of operator errors and speed response to incidents.
2. **Vehicle Crashworthiness.** Development of materials, structures, and design tools that mitigate consequences by continued advances in vehicle crashworthiness.
3. **Analyzing Safety Data.** Sophisticated data analysis can contribute to an understanding of accident causes and the assessment of existing and potential countermeasures.
4. **Emerging Challenges.** Research programs and development of data systems that can prevent accidents by providing early warning of new and unrecognized problems associated with vehicle defects or unintended consequences of new systems and technologies.

Technological Operator Aids

Lapses in the performance of vehicle operators are the largest common cause of accidents for all modes—particularly on the highway. Part of the solution is to accelerate the development and adoption of technological innovations that can minimize the consequences of driver errors and limitations. Wireless communications and Internet connections are now joining global positioning systems (GPS) in linking vehicles and their operators to the external world. Just as general aviation pilots long benefited from Loran-C navigation tools (in which the Volpe Center had an important role), GPS and new ground proximity warning systems are now being joined by cockpit instrumentation and aids that rival that of large commercial aircraft. This trend is also seen in railroad operations where new technologies make it possible to introduce a nationwide GPS that can be used to more accurately pinpoint trains throughout the system, thus offering new safety opportunities.

Automotive systems already available on some cars include lane departure warnings, aids that alert a driver to obstacles (including people) when backing up or parking, devices to detect other vehicles in "blind spots," and active cruise control to maintain a set speed-dependent distance from the car ahead. Alerting systems that can detect operator sleepiness or fatigue or signs of degraded driving performance for any reason could conceivably be used as a safety net to address situations that are common contributing factors in crashes. Work-schedule development and evaluation tools can help managers in all modes of transport including rail to manage fatigue by putting in place more ergonomic work systems. Electronic stability control systems appear to reduce crashes significantly, but, just as for antilock braking systems, may require public education to assure the most effective use. In the longer term, extensions of technologies such as these may yield automation applications that can take control of a vehicle when a crash is imminent. Extensive research is required to assess the potential safety performance and cost-effectiveness of all of these aids, accompanied by broad systems analysis to define the most effective integrated applications. Issues of user-acceptance of semi- and fully-automated systems must also be explored in depth. As part of its continuing role in the DOT Intelligent Transportation Systems program, the Center has actively participated in numerous research and development efforts in this area, including studies related to a wide range of crash avoidance technologies.

Vehicle Crashworthiness

The modern automobile offers dramatically greater crash protection to occupants than was available just decades ago. The application of sophisticated new materials and structures, improved restraint systems, and other design features, largely enabled by powerful computer simulation and modeling, can provide continued safety advances for many years to come. Although such innovations are largely implemented by industry, federal research and development plays a critical role in identifying promising approaches, providing an objective assessment of benefits and cost effectiveness, and assuring that federal regulations continue to evolve in concert with technological capabilities. The Volpe Center has a strong background in modeling both vehicle crash dynamics and the biomechanical crash responses of occupants. The Center also continues to support rail vehicle and occupant protection efforts with full-scale testing of rail cars and, more recently, supporting research that includes analyzing the forces placed upon a tank car in a derailment.

Analyzing Safety Data

Safety data have always been the starting point for understanding accident causes and assessing existing and potential countermeasures. New directions in data analysis include developing sophisticated systems for data collection and mining to enable detection and characterization of subtle or emerging causal factors, such as the Advanced Retrieval, Tire, Equipment, Motor Vehicles Information System (ARTEMIS) system described in this journal. Similar techniques can also provide a timely picture of safety trends throughout the transportation sector, thereby enabling effective interventions. The Center has a long history of developing safety information systems, most recently for Federal Motor Carrier Safety Administration (FMCSA). In today's digital world, relevant data increasingly exists in manufacturing and maintenance databases. Onboard diagnostic systems already play a significant role in analyzing specific accidents. Traffic-related information systems can know more than ever before about road operations and associated crash experience. Ongoing monitoring and oversight of transportation safety is of critical importance. The more than 200 million vehicles on U.S. highways travel almost three trillion miles each year. Even a very rare problem can cause hundreds of deaths before it becomes visible as a matter

of national concern, rather than a chance event. This is particularly the case as accidents result from a critical combination of failures, rather than a single cause. Recent issues of this type include air bag induced injuries in children and accidents associated with particular combinations of sport utility vehicle characteristics and tires. Sophisticated data analysis can help reveal these problems early on.

Emerging Challenges

Safety interventions can be designed and implemented only when the factors that cause or contribute to accidents are known and understood. Given the dynamic nature of modern society, with continued innovation in vehicle technology, fleet mix, and travel patterns, new risks arise continually. In many situations the nature of the problem may be due to a combination of the technology and driver behavior or maintenance practices. Care must also be taken not to introduce new risk factors into the transportation system. The goal of reducing adverse environmental impacts, including global climate concerns, is motivating an intense reassessment of vehicle propulsion systems. Incorporation of new materials and fabrication process into aircraft and highway vehicles could inadvertently be accompanied by new operational patterns, maintenance needs, and failure modes. New propulsion choices, such as internal combustion/electric hybrid systems, fuel cell power, and use of hydrogen as fuel, are being aggressively pursued. Each carries with it a new set of safety issues that must be resolved. Government safety responsibilities necessitate a comprehensive, objective, and detailed assessment of such innovations.

HUMAN PERFORMANCE AND BEHAVIOR

Errors or shortcomings in operator behavior are a contributing factor in the great majority of transportation deaths and injuries. Since 1991, the Center has supported DOT in running the Human Factors Coordinating Committee, a transmodal working group that provides a mechanism to enhance planning, implementation, and education related to human factors research within the transportation community.

Three areas of particular importance for future safety improvements that require explicit human factors research are:

1. **Design and Assessment of Operator Aids.** Maximizing safety benefits obtained from operator aids by matching functions and information presentation to operator characteristics.
2. **Driver Distraction.** Preventing information overload and driver distraction associated with deployment of numerous onboard electronic aids and conveniences.
3. **Understanding Operator Characteristics.** Developing improved understanding of the characteristics of the operators of transportation vehicles.

The Volpe Center has undertaken a broad range of human factors projects that make it particularly well suited to addressing these topics.

Design and Assessment of Operator Aids

Automobile and cockpit aids can significantly reduce the consequences of operator errors. Human factors considerations in the design and evaluation of communications and display technologies in aviation must be addressed. There is also a need to research user acceptance of devices such as wireless handheld systems, and to evaluate digital versus voice communications. Advances in railroad navigation systems for high-speed rail requires the evaluation of the human interface to these devices and systems. These approaches imply difficult questions: How can the maximum potential safety benefits of existing or proposed capabilities be realized? How much can each actually reduce the accident toll? How can these technologies be developed in a manner fully integrated with the needs, capabilities, and preferences of users? What designs optimize safety performance? These and other relevant questions can be answered only through human factors research that increases our understanding of the factors shaping operator behavior and operator interactions with onboard safety systems. The variety of human characteristics and transportation environments and situations makes this a daunting task, but one that is a necessity if substantial changes in the toll of death and injuries are to be achieved.

Driver Distraction

The cumulative impact of onboard operator aids raises the possibility of serious information overload for drivers who may already be coping with congested systems, adverse weather, navigation systems, phone conversations, etc. Safety professionals must consider how to minimize the degree of operator distrac-

tion associated with the use of advanced safety and convenience features. Should equipment standards and rules for use be established? There is already considerable concern over the safety implications of cell phone use while driving. A new set of potential distractions is now emerging with phones and personal digital assistants that receive email and offer onboard wireless Internet access. Will information and alerts from safety devices have positive or negative results under these circumstances? This is a complex and evolving issue, for which much research will be required to achieve satisfactory knowledge and balance. The Volpe Center is already a key player in the public-private National Highway Traffic Safety Administration (NHTSA) SAVE-IT initiative, which seeks to achieve an adaptive minimally distracting interface between the driver and onboard automated safety systems.

Understanding Operator Characteristics

Given the central role of the operator in transportation safety, it is important to understand the range of their capabilities, behaviors, motivations, and limitations. We live in a society with a diverse and aging population whose physical, perceptual, and cognitive capabilities and skills can vary widely. Many individuals may have limited knowledge of the English language. Drivers under the age of 25 show a disproportionately high level of accident involvement, as do those above 75. The effects of aging can be seen in people in their fifties, likely to drive for another 30 years or more. Attitudes toward risk, fatigue, sleep-work schedules, medications, drugs, alcohol, stress, and many other factors, alone or in combination, can affect the likelihood of unsafe actions for any operator. The focus and design of effective interventions to improve safety—vehicle and road design, traffic control devices, training, public education, licensing, laws and regulations, etc.—must be firmly based on a detailed understanding of the characteristics of the highly diverse population of drivers, pilots, and others centrally involved in transportation operations.

RISK MANAGEMENT

In addition to technological and human factors approaches, risk management is an increasingly important avenue to improved safety. It consists of identifying, accessing, and preventing risks and removing risk factors where possible. It incorporates establishing strategies and programs that balance safety priorities, including human, operational, and economic losses, against the costs of countermeasures. Risk management integrates the results of safety data analysis with the examination of relevant operational processes; characterization of system-level impacts of incidents and accidents; and assessment of the economic implications of each safety issue and candidate remedial action. The result is achievement of the maximum possible safety benefits within existing resource constraints.

ORGANIZATIONAL FRAMEWORK

Recognizing the need for organizational improvements is a key element in addressing major issues such as transportation safety. As described in the introduction of the journal the Volpe Center is now part of the Research and Innovative Technology Administration (RITA)—a new agency created by Secretary Mineta to provide a focused research, statistics, and analytical capability dedicated to furthering the Department of Transportation's mission and objectives, and to promote crosscutting transportation technologies and innovations. One key factor in the success of transportation safety measures is the need for each administration within the Department of Transportation to share information and to ensure that research in one area provides benefits across the transportation modes. A committed crossmodal focus will ensure that Research, Development and Technology (RD&T) investments are effective and tied to DOT's strategic objectives (where the safety of the transportation enterprise is foremost). RITA's role in coordinating and facilitating DOT's RD&T portfolio provides a conduit for information sharing and for defining the Department's research priorities. The Volpe Center's unique role in providing research and development support to all of DOT has enabled it to provide informal crosscutting support where lessons learned in one mode have been applied in others; RITA's more formal role in this area provides a framework for the Center's continuing safety work.