From Research to Rulemaking in the Federal Railroad Administration

J Tunna
Federal Railroad Administration
Office of Research and Development
US Department of Transportation
Washington, DC, USA

ABSTRACT
The Federal Railroad Administration's (FRA) research and development program provides the engineering and scientific foundation for rail rulemaking and enforcement in the United States. This paper describes how the program is funded and executed. Examples of projects in the track, rolling stock, train control and human factors disciplines are used to illustrate strategic direction, project selection, stakeholder engagement, technology transfer, performance measurement and evaluation. Changes in regulations from being prescriptive to performance-based are discussed, as is the shift to risk reduction and system safety management approaches.

This paper gives the reader a general understanding of rail research and development in the U.S. It is intended to encourage contacts between rail R&D practitioners for the exchange of information and to identify opportunities for future collaboration.

1 BACKGROUND

FRA's R&D program began in the 1970s with the High Speed Ground Transportation Act. This saw the creation of the Transportation Technology Center in Pueblo, Colorado and the development and testing of novel, high-speed trains.

Today's focus for the program is to improve railroad safety. Figure 1 shows the recent trends in safety performance for the U.S. railroad industry. The improvements in safety are due, in part, to outputs from FRA's R&D program. This paper provides some examples of those contributions.

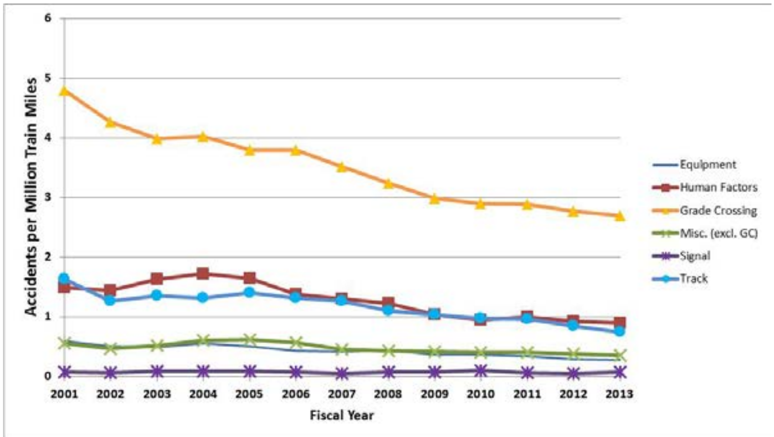

Figure 1. Safety Trends in the U.S. Railroad Industry

The safety information presented in Figure 1 and elsewhere in this paper comes from FRA's accident and incident database. This database is available on-line at http://safetydata.fra.dot.gov/officeofsafety.

FRA's R&D program is funded by the U.S. Congress with annual appropriations of typically $35 million. The funding is broken down into five program areas: Track, Rolling Stock, Train Control and Communications, Human Factors and Railroad System Issues.

Figure 2 shows the level of funding plotted against accident rate for four accident causes. The size of the circles is proportional to the harm in terms of fatalities and injuries for each accident cause.

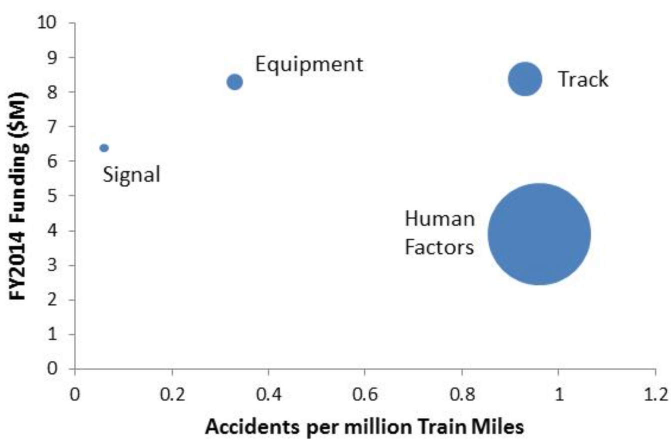

Figure 2. R&D Funding Levels and Accident Rates

Grade crossing and trespass accidents result in 90 percent of railroad fatalities in the U.S. The R&D budget includes $1.6 million of annual funding to improve safety in this area.

The budget also includes funding for Railroad Systems Issues, which cover safety risk analysis and R&D project prioritization and evaluation. It also funds projects aimed at improving environmental sustainability and reducing energy usage.

FRA conducts its R&D through other government agencies, railroad engineering companies, and universities. The Volpe Center, which is part of the U.S. Department of Transportation, is a major supplier of technical support to FRA's R&D program. There is good synergy between the FRA's R&D program and the Strategic Research Initiative program funded by the Association American Railroads (AAR). AAR's subsidiary, the Transportation Technology Center Inc., manages FRA's Transportation Technology Center and performs R&D at the facility for both the AAR and FRA. Ensco has the contract for maintenance and operation of FRA's fleet of track inspection vehicles, which includes two cars and a road-rail vehicle used mainly for R&D.

FRA publishes 4-page research result briefs and full length technical reports. These are available at http://www.fra.dot.gov/eLib/find and from the National Transportation Library at http://ntl.bts.gov/.

2 RULEMAKING AND ENFORCEMENT

FRA's Office of Railroad Safety creates and enforces safety regulations for the U.S. railroad industry. It has 14 divisions that serve as technical experts on matters of railroad safety, provide technical assistance to field personnel, and aid in the development of regulations. Staff includes 400 Federal safety inspectors who operate out of eight regional offices. Each regional administrator is supported by two deputy regional administrators, chief inspectors, supervisory specialists, grade crossing safety managers and safety inspectors for five safety disciplines focusing on compliance and enforcement in: hazardous materials, motive power and equipment, operating practices, signal and train control, and track.

The goal of FRA regulations, as with other U.S. Federal regulations, is to improve public health, welfare and safety, and the environment while promoting economic growth, innovation, competitiveness and job creation. Regulations are often initiated by Acts of Congress (e.g. the Rail Safety and Improvement Act of 2008 (RSIA)). They can also be driven by compelling safety data, and they can be created in response to public petitions.

Regulations are supported by analysis of the costs and benefits of implementation. Safety benefits can be converted to financial values using the Value of a Statistical Life and an Abbreviated Injury Scale published by the Department of Transportation. Costs of travel delays are also calculated using published guidance (http://www.dot.gov/office-policy/transportation-policy/).

In 1996, FRA established the Railroad Safety Advisory Committee (RSAC) to develop new regulatory standards, through a collaborative process, with all segments of the rail community working together to fashion mutually satisfactory solutions to safety regulatory issues. RSAC working groups are important forums for presenting and discussing FRA's research results. This is the principal means by which those results inform regulations.

In recent years there has been a growing emphasis on safety risk reduction. RSIA created a risk reduction program in which each railroad carrier will systematically evaluate and manage safety risks on its system. For passenger rail operators, FRA is proposing a similar system safety approach. This represents a shift from prescriptive regulations to a mode in which the regulated body says how it plans to achieve safety and the regulator approves and audits the plans.

Research outcomes can be achieved through regulation or voluntary adoption of new technologies or operating practices to reduce safety risk. Several examples follow.

3 PROGRAM EXAMPLES

3.1 Tank Car Structural Integrity

There was an intensive period of research and rulemaking in the 1970s aimed at improving tank car safety. Puncture of the head of tanks cars in accidents was a common failure mode. Research was conducted into the appropriate thickness and material properties for head shields to increase the tank car's structural integrity. Figure 3 shows the result of an impact test performed at FRA's Transportation Technology Center as part of this research. The impactor simulates a coupler on an adjacent car in an accident.

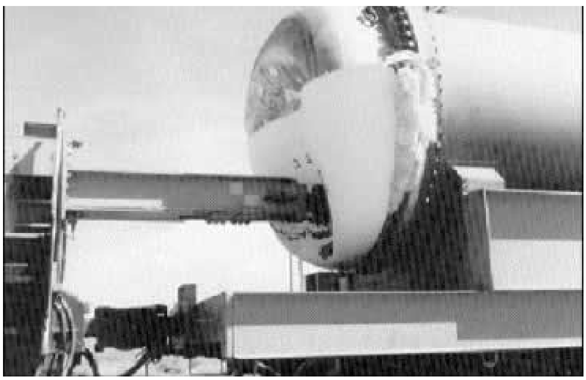

Figure 3. Tank Car Head Shield Test in the 1970s

The results of the research were published in 36 reports between 1970 and 1980 (e.g. (1) and (2)). The results were used to inform three new regulations published in 1974, 1977 and 1981. The regulations required head shields and a new design of coupler to be fitted to certain types of tank cars. The new coupler has shelves that prevent the coupler from disengaging in accidents. As the industry complied with the new regulations, the numbers of accidents with release of hazardous materials through the heads of tank cars reduced dramatically as shown in Figure 4.

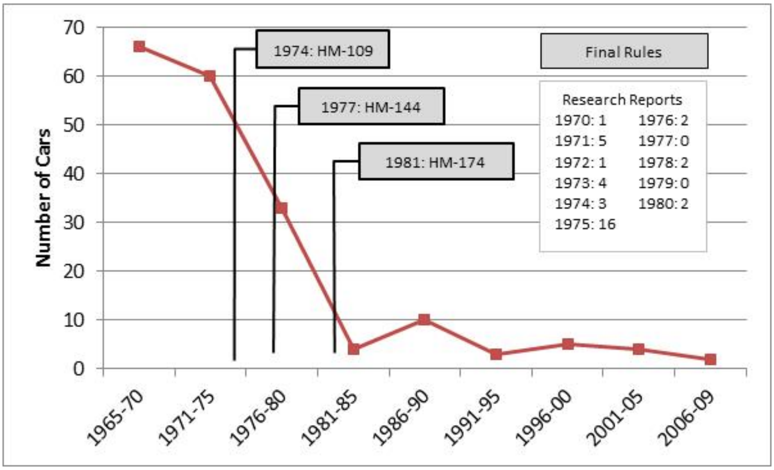

Figure 4. DOT-105,112 and 114 cars with lading loss through heads in accidents – 5 year periods

A more recent example of these safety benefits occurred at a derailment on January 14, 2008 near Springfield, IL. Figure 5 shows the aftermath of the accident. The tank car was carrying ethylene oxide, which is classified as a poisonous by inhalation hazardous (PIH) material. The head of the tank car was protected by a 17.46 mm (11/16 inch) thick shield as required by the regulations. The indentation caused by the coupler on the adjacent car (very similar to that in the earlier testing shown in Figure 3) did not result in rupture and release of hazardous material.

Figure 5. Post-derailment at Springfield, IL in January 2008

3.2 Safety Culture

In 1999, the FRA reported (3) on the results of a focus group meeting with North American Railroads to discuss the general issue of operating rule compliance. The discussions revealed the prevalence of a military style, command and control culture. There was a punitive approach to enforcing compliance to rules and a blame-based approach to accident investigations. Labor-management relations were negative and impeded safety communications. This created a desire to improve safety culture in the industry.

Table 1 lists several safety culture improvement pilot programs that were tried and evaluated. At the time, these programs were not required by regulation. The recent regulatory shift to risk reduction and system safety means programs such as those shown in Table 1 are possible steps towards compliance.

Table 1. Safety culture pilot programs

<table>
<tr><td colspan="2">Approach</td><td>Carriers</td><td>Start</td></tr>
<tr><td colspan="2">Participative Safety Rules Revision</td><td>ACBL, CSXT, KCS, CN-IC</td><td>1999</td></tr>
<tr><td colspan="2">ISROP: Investigation of Safety Related Occurrences Protocol</td><td>Canadian Pacific</td><td>2003</td></tr>
<tr><td rowspan="3">Clear Signal for Action (CSA)</td><td>EAGLES: Employee Alliance for Greater Levels of Excellence in Safety</td><td>Amtrak</td><td>2001</td></tr>
<tr><td>CAB: Changing At-risk Behavior</td><td>Union Pacific</td><td>2005</td></tr>
<tr><td>STEEL: Safety Through Employees Exercising Leadership</td><td>Union Pacific</td><td>2006</td></tr>
<tr><td colspan="2">C3RS: Confidential Close Call Reporting System</td><td>Union Pacific
Canadian Pacific
New Jersey Transit
Amtrak</td><td>2007
2008
2009
2010</td></tr>
</table>

The most recent approach to improving safety culture, the Confidential Close Call Reporting System (C3RS), is founded on the notion that a close call is an opportunity to improve safety practices in a situation or incident that has a potential for more serious consequences. C3RS allows railroad workers who observe noteworthy events to submit a confidential report. Peer review teams, consisting of labor, railroad management and FRA, then analyze groups of events to identify safety hazards and develop solutions to the threats.

Safety improvements from these pilot projects have been evaluated by FRA's Office of R&D. At one pilot site a safety culture survey was performed at the outset and after two years. Interviews were also held with management and labor. Table 2 summarizes the results and shows significant improvements (4).

Table 2. Safety culture improvements at mid-term from a C3RS pilot

	Significant Improvement	
	Managers	Labor
Labor-Management Relations	*	*
Organizational Fairness During Change	*	
Supervisor Fairness	*	*
Supervisor-Employee Relationship		*
Management Safety	*	*
Raising Concerns with Supervisors		*
Work Safety Priorities		*
Helping Behavior		*
Coworker Safety	*	

The survey also showed that employees became more engaged in the C3RS program. At midterm, 74 percent of them were willing to submit a C3RS report versus 58 percent at the beginning. Both labor and management were more convinced at midterm that C3RS was effective and that the identities of those who reported close-call events remained confidential. A very positive finding was that disciplinary cases had reduced by 90 percent over the first two years of the C3RS pilot.

At the same pilot site the effect of C3RS on the number of cars moved between derailment incidents was studied. A 31 percent improvement was found after two years into the C3RS pilot. In comparison, at two other similar sites where C3RS had not been implemented, there was no statistically significant change in derailment rates.

A similar effect was seen at a second C3RS pilot site. In this case derailments due to running through switches set in the wrong position were reduced by 50 percent (5). Prior to C3RS a switch run-through was a rule violation subject to disciplinary action. After C3RS, analysis of run-through switch incidents identified multiple factors and corrective actions to address the problems.

3.3 Rail Joint Bar Inspection

On Saturday, May 27th, 2000 a Union Pacific freight train derailed in Eunice, Louisiana. This derailment resulted in a release of hazardous materials with explosions and fires that required the evacuation of more than 3,500 people from the surrounding affected area. There was $35 million in estimated equipment and infrastructure damage. The National Transportation Safety Board (NTSB) determined that the probable cause of the derailment was the failure of a set of defective joint bars that were not found during required track inspections.

A failure of both joint bars can result in the rail ends moving relative to each other and provide a discontinuous running surface that may cause train wheels to derail. From the years 2000 to 2011, 152 derailments were attributed to joint bar failures.

Traditionally, cracks and breaks in joint bars are detected by inspectors walking along the track. The cracks being sought after can barely be seen with the naked eye, and some are easily missed. The manual, visual inspection is difficult, slow, subjective, labor intensive and inconsistent. As a result, the FRA decided to investigate other methods to locate cracked joint bars using advanced machine-vision-based technologies.

The chosen technology has cameras on-board a rail vehicle to capture images that are then evaluated to locate cracks and other defects (6). The main advantage of this approach is that the cameras can be set up to have the ideal viewing position and magnification, proper lighting, and consistent quality control evaluation processes. The approach has some disadvantages including the inability to find internal cracks that are not visible on the surface and the potential for false positive notifications.

Figure 6 shows an example of the production system that records at speeds up to 60 mph. Figure 7 shows an image taken by the system with the crack highlighted using the automated detection algorithms.

Figure 6. Production joint-bar inspection system fitted to a rail car

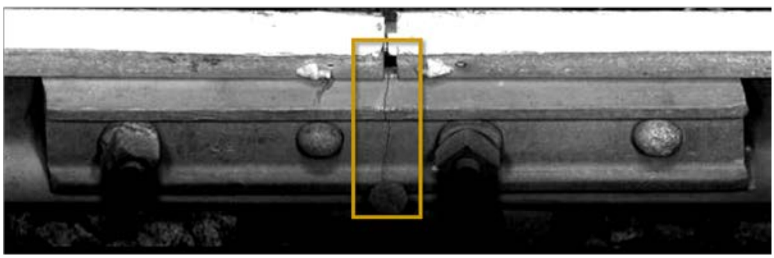

Figure 7. Image of broken joint bar detected by the joint-bar inspection system

During the many field tests of the system, several railroads showed interest in using the system before its final completion. FRA's contractor built several systems and provided an inspection service for the railroads. Table 3 shows the number of joint bars inspected between January 2008 and July 2011. The system found many defects, including fifty double (both joint bars) center breaks, which was same type of defect that caused the freight train derailment in Eunice, Louisiana.

Table 3. Automated joint bar inspections from January 2008 to July 2011

19,105 miles surveyed

- 7,205 CWR
- 11,900 Jointed

~2,600,000 joints evaluated (5,200,000 joint bars)

17,070 defective joints found including:

- 5,640 center cracks
- 1,600 center breaks
- 7,400 quarter cracks and breaks
- 150 double center cracks
- 50 double center breaks
- 2,230 FRA classified bolt defects

Figure 8 shows the history of accidents related to joint bars between 2000 and 2011. The number of accidents increased between the years 2000 and 2006, and suddenly decreased from 2007 to 2011. Several activities contributed to this decrease including a Railroad Safety Advisory Committee (RSAC) rule development and publication, the railroad's increased awareness of the problem and their incorporation of change in their processes, and the implementation of the joint bar inspection system technology. It is difficult to isolate which activity had the most significant impact on the reduction in accidents, but the turning point occurred when the new inspection technology was implemented by the railroads.

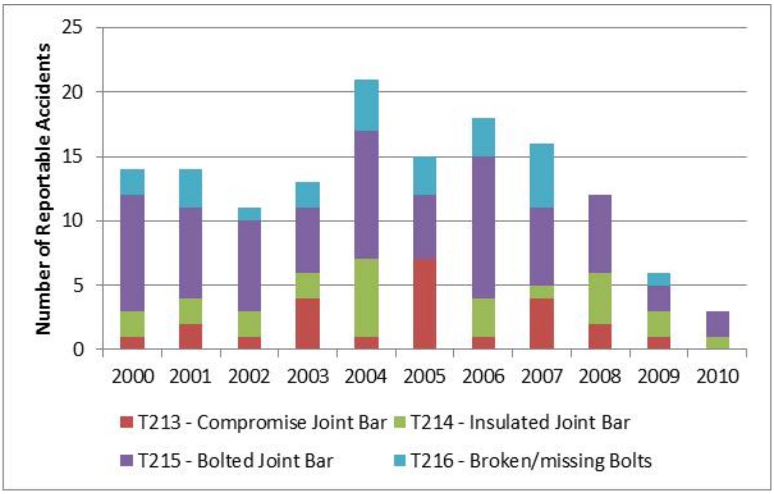

Figure 8. History of accidents related to joint bars

3.4 Employee-in-Charge Portable Remote Terminal

In response to several fatal accidents between 2002 and 2008, the U.S. Congress passed the Rail Safety and Improvement Act of 2008 (RSIA). Among the requirements was the implementation of positive train control (PTC) on certain routes by the end of 2015. In addition to preventing train-to-train collisions and over-speed derailments, PTC is required to prevent unauthorized train incursions into established work zones. FRA, in partnership with a railroad, has developed a portable remote terminal (PRT), used by the employee-in-charge of the work zone, that meets this requirement.

Current operating practice is for the engineer to stop the train before a track work zone and contact the employee-in-charge of the work zone for instructions. The employee-in-charge gives permission for the train to enter the work zone with instructions on speed and any stopping locations.

With PTC the train will be forced to stop before the work zone. The employee in charge will then use the PRT to send instructions on speed restrictions and work limits to the control center. The control center automatically sends the instructions to the PTC computer on-board the train for the engineer to follow.

Figure 9 shows an example of the PRT user interface after the employee-in-charge has entered instructions to proceed at a reduced speed and then stop. The text in the box on the right is generated from selections made by the employee-in-charge in the center of the screen. The format of the text is compatible with that currently used on manual forms.

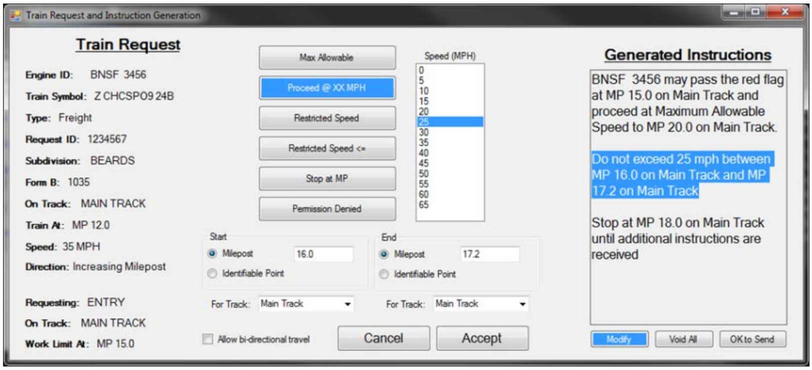

Figure 9. Employee-in-charge portable remote terminal screenshot

The PRT clearly has safety benefits over the current procedures. It avoids the possibility of error through verbal communications. PTC enforces the work limits and speed restrictions. The employee-in-charge can alter the instructions as the situation in the work zone changes. The PRT must also meet demanding standards for safety assurance.

The safety assurance of the PRT must follow the requirements in 49 Code of Federal Regulations (CFR) Part 238 Subpart I. This regulation invites the application of the IEEE-1483 specification for the "Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control." The PRT was analyzed according to these requirements and the analysis was integrated with that conducted by one of the railroads for approval of its PTC implementation plan.

4 CONCLUSIONS

Safety is the number one goal of the U.S. Department of Transportation and the main driver of the Federal Railroad Administration's R&D program. Outputs from the R&D program help create and enforce regulations, which lead to improved safety. They can also produce direct safety benefits when new technology is developed and implemented, often in partnership with the railroad industry. This paper includes examples of these different approaches.

Decades of research and testing have led to improvements in the performance of tank cars in accidents. Research results have been used to inform new regulations that the industry has followed. The benefits take several years to appear because the new regulations often apply exclusively to new tank cars, and there is a period during which older designs are phased out.

Modern regulations tend to be based on system safety and risk reduction. They rely on the railroads having a sound safety culture. The Confidential Close Call Reporting System is being adopted by several railroads as a way to improve safety culture. It began as an R&D project with a small number of pilot sites. Evaluations of these pilots showed convincing safety benefits.

The joint bar inspection system that was developed under FRA's R&D program was implemented by the railroads without the need for regulation. Public funds were used to develop and demonstrate a successful prototype. Then private funds were used to commercialize the new technology. Immediate benefits were seen when the joint bar inspection system was used.

The legislation requiring Positive Train Control drove the need for new technology. One example of the FRA working with the industry to meet this need is the development of the employee in charge portable remote terminal. The partnership started from the outset of the project and ensured a compliant and practical solution that promises to improve the safety of track workers.

More detail on these and many other FRA R&D projects can be found in FRA's electronic library at [http://www.fra.dot.gov/eLib/find.](http://www.fra.dot.gov/eLib/find)

REFERENCE LIST

1) Hohenemser, K. H., et al (1975), "Computer Simulation of Tank Car Head Puncture Mechanisms", Federal Railroad Administration, DOT/FRA/ORD/75-23

2) Peters, D. A., et al (1980), "Tank Car Head Puncture Mechanisms", Federal Railroad Administration, DOT/FRA/ORD/76-269

3) Coplen, M. (1999), "Compliance with Railroad Operating Rules and Corporate Culture Influences - Results of a Focus Group and Structured Interviews", Federal Railroad Administration, DOT/FRA/ORD/99-09

4) Ranney, J. & Raslear, T. (2012), "Derailment Decrease at a C3RS Site at Midterm", Federal Railroad Administration, RR 12-04

5) Ranney, J. & Raslear, T. (2013), "Another C3RS Site Improves Safety at Midterm", Federal Railroad Administration, RR 13-49

6) Gilbert-Serra, X. et al (2007), "A Machine Vision System for Automated Joint Bar Inspection from a Moving Rail Vehicle", JRCICE2007-40039, Proceedings of ASME/IEEE Joint Rail Conference & Internal Combustion Engine Spring Technical Conference