Research to Enhance Rail Network Performance

DETAILS

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AUTHORS

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Research to Enhance Rail Network Performance

Committee for Review of the
Federal Railroad Administration
Research, Development, and Demonstration Programs

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Transportation Research Board
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Conference Proceedings on the Web 3

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The conference was sponsored by the Federal Railroad Administration and the Transportation Research Board.

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Preface

In anticipation of updating the *Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations,* FRA proposed a new task for the TRB committee already charged with periodic peer reviews of FRA's research and development (R&D) program. With an update of the 2002 plan under way, FRA had two goals in mind for a new 5-year plan to be issued in 2007: to seek input from a broad representation of the programs' customers and stakeholders, and to take the opportunity to identify strategic directions beyond FRA's focus on safety R&D in recent years.

FRA's REQUEST FOR INPUT TO R&D STRATEGIC PLANNING

FRA's Office of R&D sought an independent view of future directions for the R&D program and asked for assistance from the committee that was already familiar with the program. FRA wanted an outreach effort that would include a broader range of voices than has contributed to the R&D planning process in the past. Research funds are scarce, and FRA sought guidance on how resources might be used most wisely to benefit rail transportation.

To engage a broad range of R&D program customers and stakeholders, individuals with many different perspectives—passenger, freight, public sector, private sector, safety, engineering, economics, and so on—were invited to participate in the Workshop on Research to Enhance Rail Network Performance, held on April 5 and 6, 2006, in Washington, D.C., and structured so that all participants had an opportunity to voice their views on strategic research directions.

The committee selected three critical issues facing the rail industry now and for the foreseeable future as organizing themes for the workshop that also could be used to categorize research topics and potential future directions for research: safety (the most obvious in support of FRA's overall mandate), capacity (related to concerns with rapid rail traffic growth in recent years), and efficiency (recognizing possible advances in technology and methods to improve railroad operations and profitability). Interrelationships or synergy among all three themes became a way to examine the whole rail system.

Both freight and passenger rail were included in the focus of the workshop. As background for the subsequent breakout discussions, the workshop themes of capacity and efficiency were each addressed by two keynote speakers: one from the freight perspective and one from the passenger perspective. The FRA Office of Safety's resource paper and workshop address also focused on freight and passenger safety issues. The workshop participants were encouraged to consider both perspectives in the breakout group discussions, and the priority research areas recommended by the committee in this report also reflect both perspectives.

PREVIOUS REPORTS TO FRA: CONTEXT FOR THE WORKSHOP

Beginning in 1995, Congress made a series of requests for National Research Council (NRC) reviews of the R&D and high-speed rail development programs of the FRA. The first request covered the Next Generation High-Speed Rail Development program. The U.S. Senate Committee on Appropriations subsequently asked that the Transportation Research Board (TRB) extend the scope of the peer review to include the R&D program, which focuses on research in support of safety regulations, beginning in 1998. The two committees appointed for these sequential projects issued numerous letter reports commenting on issues such as priority setting, feasibility of specific research projects, appropriateness of the R&D portfolio for reaching program goals, and related topics. In the FY 2001 Senate Appropriations Bill, the Appropriations Committee urged FRA to continue to support this peer review, which it has done since. In 2005, FRA continued the project with the inclusion of this workshop, and committee membership underwent a rotation, with about half of the prior membership being replaced by new members.

The themes that the current committee selected for the workshop—and many of the priority research directions identified through the workshop process—reflect the committee's recommendations in prior letter reports. For example, the concept of expanding the scope of FRA's R&D activities to include contextual (or policy) research was consistently recommended beginning in 2000. At that time, the committee felt that safety and other R&D project selection needed to be linked to an understanding of future rail industry trends to remain relevant to shifts in traffic flows and commodity mix as well as implementation of new technology and related implications for workforce requirements. Similar recommendations were stated in subsequent reports.

In its May 2004 letter report, Overall Program Directions: Need for Customer Focus and Cooperative Efforts, the committee expressed its concerns that critical decisions on program directions perhaps could be based on more inclusive inputs from program customers and stakeholders. Subsequent discussions with FRA staff led to the idea that the committee could assist with a broader outreach effort, and the workshop was part of that effort.

IDENTIFICATION OF RESEARCH DIRECTIONS

During the workshop, approximately 120 railroad research stakeholders participated in 10 breakout groups during three periods—one discussion for each of the workshop themes of safety, efficiency, and capacity. The breakout group participants represented academia; industry suppliers; Class I, regional, short line, and passenger railroads; FRA and other federal agencies; Transport Canada; industry associations; railroad consultants; railway labor; state departments of transportation; and overseas railroad researchers.

The mission of each breakout group was to identify the top five research needs in the topical areas of safety, capacity, and efficiency. The resultant breakout group research needs formed the raw material for the committee to consider in making recommendations to the FRA. The research needs statements produced by the workshop breakout groups are available on the web as follows:

- Capacity, http://onlinepubs.trb.org/onlinepubs/conf/CPW3app1.pdf;
- Safety, http://onlinepubs.trb.org/onlinepubs/conf/CPW3app2.pdf; and
- Efficiency, http://onlinepubs.trb.org/onlinepubs/conf/CPW3app3.pdf.

The committee is grateful to all the workshop participants who accepted the breakout group assignments and developed an extensive amount of material on potential future research directions that reflects their range of perspectives. Members of the committee peer-reviewed the resource papers by Robert E. Gallamore (page 13), James McClellan (page 31), and Gerard J. McCullough (page 63).

The full report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC Report Review Committee. The purpose of this independent review is to provide candid and critical comments that assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their review of this report: George Avery Grimes, Kansas City Southern Railway, Denver, Colorado; Anthony D. Perl, Simon Fraser University at Harbour Centre, Vancouver, British Columbia, Canada; John M. Samuels, Revenue Variable Engineering, LLC, Villas, New Jersey; and Joseph M. Sussman, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by C. Michael Walton, University of Texas, Austin. Appointed by NRC, he was responsible for making certain that this report was examined independently, in accordance with institutional procedures, and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Committee Findings and Recommendations

On the day immediately following the workshop, the committee convened to review the output of the workshop, principally the research needs identified and prioritized by the breakout discussion groups. Given the volume of the material (roughly 150 research statements), the committee laid out a process for each committee member to review the material and individually rank the top five priority research needs under each of the workshop broad themes. After completing their individual review and ranking process, the committee agreed to convene again to consolidate their individual rankings and to develop a consensus prioritization of the major research directions that it would recommend to FRA. The following summary of the committee's findings and recommendations for research was developed during a committee meeting in late June. The recommendations are divided into two parts, the first related to overall management of the R&D program, and the second a listing of priority research directions.

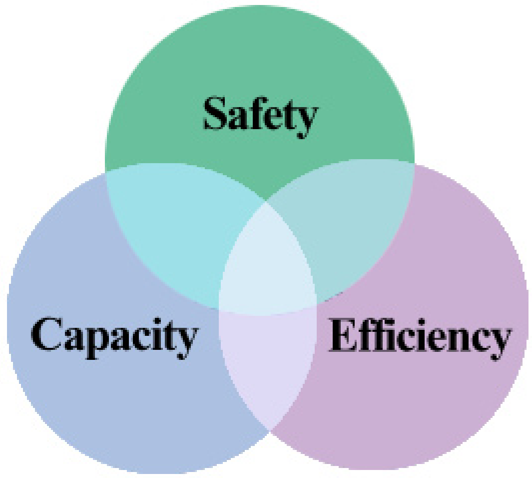
CONFERENCE THEMES

As mentioned above, the committee selected three critical issues—safety, capacity, and efficiency—as organizing themes for the workshop that were used to categorize research topics and potential future directions for research. Interrelationships or synergy among all three themes provided a way to look at the whole rail system.

Safety has been the main theme running through nearly all FRA R&D work since the 1970s, and its continuing importance needed no justification.

Capacity, or rather the shortage thereof, is the focus of considerable discussion among transportation providers and users. Railroads, especially in the west, have absorbed huge increases in both train-miles and ton-miles in recent years. Now, however, many railroad corridors are at or near capacity as currently configured. Railroads have responded by adding capacity as well as shedding some low-margin traffic to make room for higher-margin business. A railroad capacity problem would be of minor national importance were alternative modes able to handle substantial growth. The reality is, however, that highway construction is not keeping up with the growth in demand. Additionally, the recent rise in fossil fuel energy costs has shifted more intermodal traffic from highway to rail. Many public officials look to the railroads to provide a capability for handling a rising tide of freight and passenger commuter traffic.

Efficiency, the third theme for the R&D workshop, has many guises and suggests many avenues for progress in railroading. There are close linkages among productiv-



Conference themes.

ity, profitability, innovation, and investment. The public benefits of deregulation under the Staggers Rail Act were precisely these—that by allowing market forces to guide the adjustment of industry supply to market demand, firms squeezed out waste and earned sufficient profitability to afford reinvestment. Other efficiency considerations are also important in setting public policy for transportation, including fuel efficiency, properly valuing environmental resources and impacts, and the effectiveness of safety regulation and investments in reducing casualties and property damage.

The workshop also focused on some important factors relating to the trade-offs (positive and negative) naturally encountered in considering priority choices between or among *safety, capacity*, and *efficiency*. For example, there sometimes may be inherent conflicts between a firm's drive for improved efficiency and its obligation for compliance with FRA's safety rules, or a capacity bottleneck resulting from an efficiency-driven shortage of trained and rested labor. There are numerous examples of where the three themes reinforce each other—where capacity additions such as improved rail and signaling systems make an operation safer or more efficient, or where a safety investment such as positive train control (PTC) adds line capacity.

FRA's emphasis on safety research in recent years has addressed safety issues related to freight and passenger operations. Workshop discussions made clear the coincidence of freight and passenger concerns about capacity and efficiency issues, which are inextricably connected within the overall rail network.

KEY FINDINGS

Although the breakout groups were not tasked with considering the current R&D work being conducted by the FRA, the committee concluded that ongoing research being pursued by the FRA should continue and not be given a lower priority solely because of proposed new research resulting from this research needs identification process.

The list of new priorities under Recommended Research Directions (below) does not imply that all current research activities should be discontinued. Consistent with the committee's previous reviews (see Previous Reports to FRA: Context for the Workshop in the Preface), the committee endorses the continuation or completion of the current FRA research tasks, as follows:

- Completion of the Nationwide Differential Global Positioning System (NDGPS) network;
- Continued development and deployment of positive train control (PTC) technology;
- Continuation of ongoing fundamental research in key railway materials and components, including materials and designs for equipment, wheel–rail dynamics, braking technologies, and wayside detection devices—funding of the FRA-AAR joint Heavy Axle Load Program is one example;
- The Confidential Close Call Reporting System Demonstration Project, which holds promise for improving the understanding of accident causes, particularly those related to human factors; and
- Tank car safety and hazardous materials risk research.

RECOMMENDATIONS FOR FRA's R&D PROGRAM MANAGEMENT

In this section, the committee makes the following recommendations on the overall R&D program management.

Where FRA Takes the Lead

FRA should choose research areas that are appropriate for publicly funded research and that are realistic within budget constraints. This category would include advanced research that typically would not be funded by railroads or railroad suppliers because of a perceived higher risk of failure. (This does not mean less care should be used in selecting high-risk projects under a constrained budget, but it does mean FRA should not shy away from a well-calculated risk because of "fear of failure.") On the other hand, if some research is deemed more appropriate for private industry (or if private institutions are more capable of performing the work), then FRA should make those distinctions and let industry take the lead. Opportunities for jointly funded research should be continued as appropriate. This model for "division of labor" should be made explicit in the five-year plan.

Avoiding Undue Fragmentation or Scattering of Research

The committee is concerned that focus on some critical areas can be lost through fragmentation of research efforts (for example, too many small projects). The committee recommends that FRA develop a concept of scoping studies as a screening mechanism to explore some areas that show promise for future research before launching research projects that may scatter resources. Contracting for "white papers" could provide a cost-effective way of capturing current knowledge and suggesting where more research is needed.

Meeting Expectations

The workshop participants will be waiting for results of their efforts in providing input to the R&D priorities process. To the extent possible given budgetary constraints, the five-year plan should indicate which research directions and related projects will be pursued and provide a schedule of when research results can be expected. FRA should disseminate results of completed research as quickly as possible and speed up delivery of final reports. FRA's online "Research Results" is an important way that research findings are being disseminated.[1]

Regulatory Issues in R&D Implementation

The committee recommends that FRA explore the extent to which regulations may be an impediment to the implementation of new technology that would enhance safety and efficiency. FRA regulations are designed to improve rail safety, but many are overly specific and out-of-date. If new technology and improved methods can be employed to get the same results, how can the regulatory system react to such advances in a more timely way? An alternative approach, funded by FRA and conducted by the Kennedy School of Government, took a broad look at the potential benefits and limitations of performance-based regulations (*1*). (For more specific research recommendations related to changes in safety standards, see Performance-Based Standards, Use of Benefit–Cost and Risk-Based Analysis, and Improved Accident–Incident Data under Recommended Research Directions below.)

RECOMMENDED RESEARCH DIRECTIONS

Based on input received from the R&D program's customers and stakeholders through the workshop process, the committee is responding to FRA's request to produce recommendations for future *strategic directions* for research.

In a number of instances the breakout groups had difficulty in assigning research needs to the three categories of safety, capacity, and efficiency because, more often than not, capacity and efficiency improvements also have an important impact on safety. In developing recommendations for future research directions, the committee also found substantial overlap among the categories. Accordingly, most of the committee's recommendations for future FRA research priorities, while addressing capacity and efficiency improvements on U.S. railroads, will generate concurrent safety benefits. Conversely, valuable research that is expected to have important capacity or efficiency benefits should not be ignored by FRA because it is not aimed primarily at safety.

What follows is the committee's collective perspective for a priority ranking of the key research directions for consideration in FRA's next five-year strategic plan for R&D, with the first being the highest priority. Under each broad topic, lists of subtopics are illustrative of the sorts of research to be undertaken but are not meant to be all inclusive. These subtopics are largely drawn from the research needs statements produced by the workshop breakout groups. These statements are available on the web: Capacity, http://onlinepubs.trb.org/onlinepubs/conf/CPW3app1.pdf; Safety, http://onlinepubs.trb.org/onlinepubs/conf/CPW3app2.pdf; and Efficiency, http://onlinepubs.trb.org/onlinepubs/conf/CPW3app3.pdf.

1. Positive Train Control and Related Technologies

FRA's rulemaking, "Standards for Processor-Based Signal and Train Control Systems" (49 CFR Part 236, Subpart H), places responsibility on all railroads to adopt a software management control plan for any new processor-based signal and train control equipment placed in service. Suppliers are implicitly responsible for accurate representations of their components and software. Thus, the committee concludes that the role of FRA research should be to identify and solve the technical and regulatory obstacles to migrating the current train control systems to a fully operational PTC system.

Lessons learned from current pilot programs should be pursued, but funding for additional pilot programs would be less and less productive.[2] The cost of implementing PTC systems is a large impediment to implementation, and working with the railroads, FRA might encourage development of cost-effective components of PTC that could be introduced incrementally as they become available. FRA should be emphasizing development of technical and regulatory solutions that would potentially reduce implementation costs and would undertake the following:

- Develop communication systems to support PTC, including subsystems dedicated to maintenance of way (MOW), track forces, on-board data, train health (e.g., locomotive operating characteristics, train braking system status, and degrading components), train and MOW equipment location, and data integration:
  - Analyze emerging communication systems;
  - Analyze human factor–related train control issues such as increased data flow and transmissions, proper information displays, and crew overreliance on system information; and
  - Develop management techniques to make best use of rich data producing sensors and railroad system information.
- Develop a vital and virtual dark railroad signal system with broken rail and switch point detection capability, including the following:

  - Provision of fail-safe–fail-operational train movement authority without wayside signals; and
  - Broken rail and switch point position information delivery to locomotive or central dispatching location (office).
- Develop cost-effective collision avoidance technology for trains and MOW equipment:
  - Develop locomotive and MOW equipment warning systems for conflicting moves; and
  - Quantify derailment and collision prevention cost–benefits for lower-cost systems.
- Conduct cost–benefit studies of PTC systems that are interoperable on all railroads:
  - Determine interoperability costs and benefits;
  - Calculate train and track integrity determination costs and benefits;
  - Calculate moving train block costs and benefits; and,
  - Calculate train operations and braking costs and benefits.
- Conduct human factors research on the impact of PTC systems on new and established employee training including locomotive cab displays and communications requirements.

2. Performance-Based Standards, Use of Benefit–Cost and Risk-Based Analysis, and Improved Accident–Incident Data

As mentioned in Regulatory Issues in R&D Implementation above, the committee is interested in analysis of the relationship between the regulatory system and implementation of new technology. A value of performance-based standards is that they allow regulated operators to use the most cost-effective methods to meet the regulator's desired safety goals. The consensus of the committee is that risk-based research, with industry participation, should be conducted in support of performance-based safety standards. FRA R&D should also be conducted to find and evaluate opportunities to deploy cost-effective automated inspection techniques to be used in lieu of or to supplement manual inspections. A related objective would be to develop improvements in the collection of accident–incident data so as to better perform cost–benefit and risk analysis in prioritizing R&D projects related to regulatory standards and the development of automated inspection technology.

- Conduct research on the feasibility of performance-based standards for operations such as the following:
  - Provision for origin-to-destination train operations without the need for intermediate train inspections;
  - Daily and periodic locomotive inspections;
  - Train speed limits in dark territory;

  - Remote control of rolling stock; and
  - Roadway worker protection.
- Continue R&D of automated inspection technology including
  - Automated track inspection vis-à-vis manual inspection,
  - Wayside rolling stock inspection detectors, and
  - Rolling stock on-board diagnostic equipment.
- Develop improved accident–incident root-cause data collection to support performance standard development and automated inspection technology.

3. Highway–Rail Intersection Safety and Trespasser Casualty Mitigation

The breakout groups proposed a number of varied approaches to this research area. The following committee recommendations are based on the need for cost-effective, grade-crossing crash mitigation solutions, improved passive and active warning crossing systems, and improved human factor and behavioral analysis of highway users and trespassers.

- Highway–rail intersection separation studies:
  - Develop a "white paper" on the costs of various techniques, for various applications, to achieve grade-crossing separation; and
  - Prepare cost analysis of total rail network grade-crossing separation vis-à-vis rail operation benefits.
- Trespasser research, including the following:
  - Conduct root cause and human factor analysis of trespasser and grade-crossing accident–incident victims;
  - Study the application of video and sensor technology to trespasser and grade-crossing violation detection;
  - Conduct a Pareto analysis[3] of trespasser incidents; and
  - Conduct trespasser and grade-crossing incident geographic and demographic "hot spot" research.
- Cost-effective, passive highway–rail intersection warning devices:
  - Research grade-crossing warning systems (and regulatory requirements) that do not rely on track circuits;
  - Conduct studies related to cost-effective devices to alert highway users, in their vehicles, of approaching trains; and
  - Conduct studies related to cost-effective devices to alert dispatchers, engineers, and on-board systems of instances of genuinely obstructed crossings.

4. Human Resource Management

The committee recognizes that this is a difficult and complex research subject area, but it is critical because of changing workforce demographics, cultural shifts, and dramatic changes in railroad technology. In recommending this research direction, the committee chose to emphasize areas where it thinks FRA research is appropriate and necessary, particularly in light of the fact that the rail industry research program has not covered human factors in many years. Of critical importance are human factors issues related to the design of locomotive cabs and MOW equipment, fatigue, and training. Interrelated issues include scheduling of safety-sensitive personnel, scheduling of trains and MOW operations, and developing staffing levels with some degree of ready-reserve (or surge) capacity. Although much of this work falls within the domain of individual railroads, FRA's research can contribute to a consistent approach and improved tools for the industry's own analyses. The FRA research should also take account of the fact that some of the most important issues in human resource management, including fatigue and work-rest cycles, are subject to labor-management collective bargaining. Research findings and recommendations need to take this circumstance into account explicitly.

- Staffing and assignment of crews:
  - Conduct sensitivity cost–benefit analysis of providing metric-based analysis of crew staffing;
  - Conduct cost and risk analyses of instances in which a crew reaches its hours-of-service limit and those occurrences in relationship to length of runs or other measures of scheduled work; and
  - Develop optimization techniques for crew utilization and management.
- Human factors: Research the safety and task training needs of new-generation and experienced employees vis-à-vis the introduction of new railroad technology.
- Operational scheduling: Develop tactical locomotive, crew, car assignment, train block assignment, and "MOW window" scheduling systems.
- Fatigue management:
  - Continue scientific research on the causes of and countermeasures to fatigue,
  - Research and report on other industry studies on fatigue, and
  - Investigate the use of cognitive tests and hardware solutions for testing unacceptable levels of fatigue or insufficient alertness.

5. Network Capacity Analysis

This research area is also multifaceted. The committee recognizes that currently, and for the immediate future, the capacity of the U.S. freight railroads is reaching its maximum ability to move freight. This is especially true in certain key corridors and transportation hubs. Further complicating this concern is the public interest in increasing the number of commuter and light rail passenger operations in metropolitan areas and in planning by states and regional groups for increased intercity rail passenger services. Outside of the Northeast corridor, the vast majority of commuter and intercity rail services—existing and planned—require tracks and rights of way owned by freight railroads that are strained by increases in freight traffic. It is also likely that with anticipated growth of fuel costs and concern over environmental impacts, public policy, not to say constraints within the trucking industry, will motivate a modal shift of freight to the railroads. In this research area, the committee is recommending the development of analytical tools, metrics, and methodologies that can be commonly adopted or accepted for capacity studies and analyses of proposed public–private partnerships. The committee is not suggesting that FRA undertake these studies or analyses, but to provide instead, through its R&D program, tools for use by industry and government agencies. It may be important to involve potential users of these tools, in industry and government, in developing and perhaps funding these tools. As an example, examining causes of delays to trains and developments needed to reduce delays are issues that could be addressed by some of these tools and metrics.

- Means to determine capacity: Develop a capacity model (or models) applicable to main lines, line segments, and terminals—models that can be widely accepted and adopted by industry to determine theoretical capacity, bottlenecks, and opportunities for investment.
- Metrics for measuring capacity improvements: Develop a set of industry-agreed-to line segment, corridor, railroad, and regional metrics for on-time train performance, yard congestion, and locomotive and car utilization performance measurements.
- Public–private partnerships: Develop a widely acceptable methodology to quantify the benefits of public investment in rail network capacity, including energy and environmental considerations.

6. Energy Efficiency and Environmental Issues

Energy and environmental research needs have been indicated in several of the categories above. The committee has identified some needs that are unique to railroad energy and environment that merit separate attention, as follows:

- Investigate the efficiency and environmental impact improvements of alternative fuels;
- Develop fuel-saving tactics related to train handling, consist management, and locomotive idling;
- Investigate computer-assisted locomotive handling techniques; and
- Develop strategies to mix traditional train-braking consists with electronically controlled pneumatic-brake train consists.

In conclusion, the committee recognizes that in the broader context of freight and passenger rail operations, safety, capacity, and efficiency are closely interrelated. Any R&D activity should take into account the potential impacts and consequences on all three of these important aspects of railroad operations. That said, the research projects listed above are the priorities the committee believes will best serve FRA's goals and ever-present funding constraints. These priorities build on and complement FRA's past and current research priorities and demonstrate the need for and importance of industry and government cooperation in conducting effective research.

NOTES

1. The committee also urges FRA to continue to maintain a repository for prior research reports to protect availability of these resources in the future.
2. The impetus for FRA support of PTC research and development came largely from the policy goal of incrementally higher speeds for intercity rail passenger services in existing freight corridors. (To be sure, NTSB and FRA have wanted to accelerate PTC development to reduce train collisions as a cause of casualties at any speed.) Current pilot PTC projects were funded through the Next Generation High-Speed Rail Demonstration Program, which ended in 2005.
3. Pareto's Principle or Pareto's Law (or the 80:20 Rule as it is sometimes called) can be an effective management tool. Essentially it means that in anything a few items (20 percent) are vital and many (80 percent) are relatively unimportant—or that 80 percent of the benefit can be obtained with action on the top 20 percent of opportunities.

REFERENCE

1. Coglianese, C., J. Nash, and T. Olmstead. *Performance-Based Regulation: Prospects and Limitations in Health, Safety, and Environmental Protection*. Report No. RPP-03. Regulatory Policy Program, John F. Kennedy School of Government, Harvard University, Cambridge, Massachusetts, 2002.

SETTING THE STAGE

SETTING THE STAGE

Context for the Workshop

FRA Railroad Research and Development Sponsorship, 1966–2005

Robert E. Gallamore, *Northwestern University*

FRA asked TRB to assist in the review and planning of its research and development (R&D) program by commissioning a task force of industry experts familiar with both FRA and railroad industry research activities. Under FRA sponsorship, TRB organized and has maintained for the past 8 years its Committee for Review of the FRA Research, Development, and Demonstration (RD&D) Programs (the review committee), under the leadership of four different chairs. In early 2005, FRA asked TRB to call on this committee and other resources to gain input from stakeholders and customers for an update of the FRA Five-Year Strategic Plan for Railroad Research and Development. The current effort serves as a follow-on to the report of the same title requested by the Senate Appropriations Committee and published by FRA in March 2002. The review committee took on this assignment with enthusiasm and is helping FRA develop a public workshop on railroad research needs, April 5 and 6, 2006.

HISTORICAL AND CONTEMPORARY SETTINGS OF RAILROAD TECHNOLOGY

The American railroads are a venerable and valuable, yet vulnerable, industry. Railroads were “the nation’s first big business” in the famous phrase of Alfred Chandler, and because they were “imbued with the public interest,” railroads were the first industry to come under comprehensive government economic, safety, and retirement system regulation. Railroad technology could already have celebrated its bicentennial, because the first demonstration of a locomotive pulling a train of cars on a track (the proper definition of a railroad) was conducted by the Cornishman Richard Trevithick at Pennydarren, South Wales, in 1804. To skeptical observers, Trevithick demonstrated an important fact, that a high-pressure steam locomotive could pull more than its own weight without its wheels slipping uselessly on the smooth track.

In the 200 years since then, railroads have induced a remarkable record of technological improvements—more powerful steam locomotives, swivel bogies, iron rail and then steel rail, pneumatically powered and controlled brakes, electric track circuits and fail-safe signaling systems, the “automatic” coupler, applications of electric lighting and traction, centralized traffic control, diesel–electric locomotives to replace steam engines, “automated” classification yards, portable two-way radio communications, applications of computerized information management systems, remote switching control, and initial demonstrations of positive train control (PTC).[1]

These and other technological innovations have helped the railroads remain young despite their old age. The railroads have reinvented themselves time and again. They were the first practical means of overland transportation faster than horseback and today provide about 15 billion passenger miles of service to commuters and intercity travelers annually. They enabled the American continent to be developed beyond its seaports and inland rivers—and with means more efficient than animal-powered wagons—tying the nation together as an economic miracle and an arsenal of democracy. The railroads presaged the Interstate and Defense Highway system as an efficient passenger and freight network to serve all regions and major cities of the land. Today, they move more ton-miles of freight than any other mode of land transportation, and they do it with average costs and rate levels that have continued to decline in price-adjusted terms—and for many movements, even nominally—over the past quarter century.

Today’s efficient unit trains of low-sulfur coal move thousands of miles from mines to power plants, offsetting a need for more imported petroleum or natural gas or the expanded nuclear generation of electric power. Unit trains of grain help America’s farmers remain prosperous while feeding much of the world. Efficient railroad movement of chemicals feeds hundreds of basic industries, from agriculture to zinc plating, while keeping many hazardous commodities off the highways and thereby saving lives because of railroading’s fine safety record. Intermodal movement of domestic and international containerized freight, using double-stack unit trains, has been a boon to American participation in world trade; although congestion in the movement of containers away from ports and border crossings and near inland intermodal terminals has been an issue requiring more public attention, it is impossible to imagine handling today’s volume of merchandise trade by highway alone.

All of these developments, so crucial to the way our economy works and the benefits it brings to our standard of living, depend on modern, high-capacity, efficient, and safe railroads. The state of the railroads, in turn, is the consequence of railroad technology improvements and capital investment in railway enterprises.

It is helpful to remember the old mantra, “the fundamental efficiency of the steel wheel on steel rail”: a marriage of low-friction movement, the durability of high-strength steel, and the physics of entraining heavy tonnage behind a well-designed pulling machine. But the heart of the story is not fundamental mechanics and physics but rather applied economics. The real reason railroads have become the “enduring enterprise” (*1*) is that they and their suppliers have kept abreast of new technological possibilities and have incorporated these innovations into the billions of dollars of annual (private) capital investments made to increase and maintain railroad capacity for handling the nation's freight. In other words, the main way by which inventions become innovations and are diffused into more productive industrial capacity is through reinvestment.

Technology improvements are only rarely retrofitted as stand-alone devices; more often, they are incorporated within (made part of) broader investments in new equipment or facilities; new technology is deployed to ongoing operations by its incorporation in capital reinvestment. This particular process of technology diffusion and expansion of productive capacity is the primary reason we say that railroads must "earn their cost of capital." The railways must be able to reinvest to move capacity, efficiency, and safety performance ever forward.

BRIEF ECONOMICS OF TECHNOLOGY IMPROVEMENT IN RAILROADING

If the remarkable flow of new technology available through reinvestment is the "fountain of youth" for railroads, then we should try to better understand how it all comes about—which can be done by exploring five major characteristics of the process, as follows.

First, invention seems to occur in spurts rather than a steady stream, as might be inferred. Historical railroad inventions surged in the 1820s and 1830s (e.g., steam locomotive improvements, rolled iron rail, swivel bogies, and telegraphy), the 1870s and 1880s (e.g., Westinghouse air brakes, Robinson track circuits, Janney couplers, and electricity applications), and the 1920s and 1930s [e.g., centralized traffic control (CTC), semi-automated classification yards, roller bearings, diesel–electric locomotives, and passenger train streamlining]. Another surge of innovation appears to have occurred in the 1980s (e.g., premium steel rail and other track components, microprocessor applications in locomotives and signals, fiber optics, PTC concepts and subsystems, and alternating-current traction motors).

Second, a demonstrable lag is typically observed from invention (the feasible idea) to innovation (the practical commercial application), just as from scientific discovery to engineering application. Gerhard Mensch, a German economist, documented the lag from invention to innovation for numerous important technologies and commercial products historically (*2*). In the first half of the 19th century, the lag averaged 62 years for a list of invention-innovations such as electricity, the coke blast furnace, photography, crucible steel, Portland cement, and vulcanized rubber. In the second half of that century, the lag averaged 50 years for high-grade steel, the incandescent light bulb, steam turbines, aluminum, internal combustion engines, aspirin, telephones, and rayon. In the first half of the 20th century, the lag from invention to innovation declined significantly to an average of 27 years for the likes of radar, radio, television, penicillin, the jet engine, and xerography.

The average lag likely declined still more in the second half of the 20th century, with innovations such as personal computers, digital data storage, cellular telephones, the lunar landing module, smart weapons, and the Global Positioning System. We can safely generalize that the lag from invention to successful commercial introduction has declined significantly over time and will continue to do so under the pressures of modern business logistics and marketing strategies, which emphasize minimizing the holding of inventory (especially goods at rest in the supply chain–like inventions on the shelf) and time to market.

Mensch did not include diesel–electric locomotives, but he could have, and Harvard economist Edwin Mansfield did. Mansfield tracked the replacement of steam locomotives by diesel–electrics over the period 1925 (practical invention) to 1959 (total saturation), finding great differences among railroads in the rate of substitution of diesels for steam engines and explaining most of the variation by differences in the profitability of the investment, railroad size, and the beginning point of dieselization (*3*). Understandably, the major coal-hauling roads did not want to offend on-line customers, and these carriers had ready access to inexpensive coal for steam fuel. In keeping with the theme of continuous improvement in railroad technology, some of the most dramatic enhancements in steam locomotive technology occurred during this period of impending transition to diesel.

World War II delayed dieselization, because the War Production Board had higher priorities for the manufacture and use of diesel engines and petroleum to fuel them. After the war, dieselization progressed rapidly, especially when the railroads decided to address the issue as a systemic cost-transformation strategy that involved not only the purchase of new diesel locomotives but also the abandonment of coaling stations, water standpipes, and roundhouses and a steady reduction in the number of steam-related employees, such as specialized mechanics and firemen.

Third, the economic process that moves inventions or technology improvements into practical application is like the psychological process of stimulus–response. A new product must have benefits beyond current technology that warrant investment in the replacement of current equipment or expansion of total capacity. The more profitable the use of the new technology, the faster it will be deployed. Mansfield's extensive research showed a faster rate of diffusion for the innovations that were more profitable and that required smaller investment outlays. Also, not surprisingly, Mansfield found that the propagation rate was faster when the innovation did not replace durable equipment, when the industry was growing, and when the innovation was relatively new (*3*). This last point should be modified somewhat by considering the bandwagon effect that occurs when nonadapters see competitive pressures to go along—that is, when the risk of falling behind competitively exceeds the risk of pioneering a new technology.

In an extension of Mansfield's work, I have hypothesized elsewhere that the diffusion of new innovations in the railroad industry will occur more rapidly when the replacement scope is confined to single components or stand-alone units within the mix of rail facilities and equipment (e.g., a locomotive improvement or a premium turnout) rather than network-changing investments (e.g., track gauge, a large signaling or dispatching system, electronically controlled braking, or automatic couplers). Also, innovations limited to a single railroad function or geographic area and under the control of a single departmental officer (e.g., ballast regulation, rail grinding and lubrication, or the introduction of concrete or composite cross-ties) will diffuse more rapidly than those that require enterprise-wide system transformations (e.g., dieselization, digital radio communications, or PTC). Some innovations in this last category may properly involve industry agreement on standards for interoperability, new labor agreements, changes in FRA safety regulations, or even legislation—all of which delay the time to implementation.

Fourth, railroads almost certainly have underinvested in R&D and new technology deployment over the years. This issue encompasses two aspects: the perceived rate of return (yield) on R&D expenditures and the financial ability to risk scarce investment dollars on uncertain outcomes (the R&D itself usually being more risky than the deployment of innovations). Several well-known economists have published studies indicating that the rate of return on R&D investment in American industry compares favorably with that of alternative capital investments. Griliches estimated private rates of return to R&D investments in industry at 27% (*4*). Mansfield's case studies showed a median private rate of return of 26%, while social returns were much higher, 56%. Terleckyj's econometric study of R&D returns from 1948 to 1966 (*5*) showed private direct returns in manufacturing industries were 30%, while indirect yields were 80%; private returns in nonmanufacturing industries could not be demonstrated, but the return on all R&D available to nonmanufacturing industries was an astounding 187%! That these authors are all fine economists and that they reached similar results are important, but the studies are now rather dated and are not directly related to the railroad industry (except for some of Mansfield's cases); new research is needed in this area.

Finally, availability of funds for investment in technology is a major determinant of the rate of diffusion of improvements. My study of the beneficial effects of the Staggers Act for improvements in railroad productivity, a major portion of which was passed along to shippers in the form of lower average rate levels, draws a strong link from improved industry profitability in the post-Staggers period to reinvestment in capital goods, which by embodying new technology such as better steel rail, superior quality in maintenance of way machinery, and electronic controls in locomotives contributed to the "virtuous upward spiral" of improving railroad fortunes in the 1990s (*3–6*). It follows logically but is difficult to prove that if FRA R&D expenditures help expand the inventory of profit- and safety-enhancing inventions and innovations for use by railroads, then these new technology applications will gradually be diffused into the industry and will result in both private and social benefits at handsome rates of return.

FRA RD&D PROGRAMS IN PERSPECTIVE

The FRA mission is both regulatory and promotional. FRA is responsible for establishing and maintaining regulations intended to ensure the safe movement of passengers and freight and to help prevent accidents from occurring at intersections of railroads and highways or streets. FRA's rail safety regulatory authority was transferred from the Interstate Commerce Commission (ICC) after FRA was established within the U.S. Department of Transportation at its birth in 1966. FRA has a parallel but lesser mandate to promote the rail mode as a viable part of national transportation policy. This dual mission has at times appeared to be somewhat internally contradictory, as it might be argued that if FRA issued onerous safety regulations, they could hurt the rail mode in competition with trucks or water carriers. Indeed, trade-offs are to be made between some regulatory requirements and least-cost operating practices narrowly construed. Fortunately, experience tells us that, most of the time, "safety is good business."

Also, without fully achieving the promise, FRA has taken initial steps to move its safety regulation away from detailed prescription of inputs (e.g., miles traveled or hours between inspections) and more toward performance standards. The ultimate goal of this policy modification is to achieve higher levels of safety with limited resources devoted specifically to safety applications, or the reverse: equivalent safety for the expenditure of fewer dedicated resources. If pursued skillfully, performance standards can help accelerate the pace of new technology deployment, because the regulatory emphasis shifts from how often existing technology must be inspected to how well the new technology performs in its working environment.

Surprisingly, in the initial years after transfer of the safety mandate from ICC, FRA investments in RD&D were much more focused on high-speed ground passenger transportation than on the support of safety rule making and enforcement. In 1966, FRA received responsibility for higher-speed passenger service—at that time, mainly the introduction of Metroliners on the Northeastern Corridor between Washington, D.C., and New York City, and the development of air cushion vehicles—from the Department of Commerce. To test high-speed systems, FRA established and operated the Transportation Test Center (now Transportation Technology Center) at Pueblo, Colorado, and established the Northeastern Corridor Improvement Project—later expanded to include electrification north of New Haven, Connecticut, to Boston, Massachusetts—as well as the Next Generation High-Speed Rail Passenger Service Program, part of FRA's R&D activities until recently. Although operation of the Pueblo test center and some fairly heavy investments in high-speed rail technology were visible activities in the agency's first decade, the picture soon changed.[2]

By the force of events in the 1970s, FRA's focus turned from the promotion of passenger rail service to addressing the economic collapse and bankruptcies of railroads in the Northeast and Midwest. While responsibility for reorganization of the northeastern railroads fell to a new agency, the U.S. Railway Association, FRA was deeply involved in preparing material for the Secretary of Transportation and studies mandated by Congress. The publication of *A Prospectus for Change in the Freight Railroad Industry* spelled out context for FRA's legislative recommendations (*7*). Most important for FRA's R&D program and its safety regulatory function was that the 1970s were punctuated with a string of highly publicized railroad accidents involving the movement of hazardous commodities (also known as dangerous goods) by tank car. One of the worst of these occurred at

Waverly, Tennessee, in 1978, when a tank car exploded during the cleanup of a derailment from 2 days earlier, killing 16. Such catastrophic accidents involving hazardous materials led to an important collaboration among FRA, the railway supply industry, and private-sector freight railroads. A way had to be found to address the danger presented by tank car derailments, explosions, and fires.

The genesis of the tank car safety issue in the late 1960s and early 1970s was that many new tank cars used for rail transportation of liquefied petroleum gas (LPG) had recently been built to a new, more efficient design and were much larger than the cars they replaced. In the same time frame, the deteriorating financial and physical condition of some of the railroads caused more frequent derailments. Worse, aspects of the new design made tank cars vulnerable to rapid and catastrophic failure when involved in a serious derailment—sometimes resulting in multiple explosions and conflagrations. The notoriety of the violent tank car explosions and fires stimulated plenty of ideas for regulatory and operating solutions, but almost no data existed on what technical counterstrategies would be truly effective.

In ensuing debate about how to correct the problem, two cooperative research programs were formed. To address derailments, the Track–Train Dynamics Project—involving railroads, the railway supply industry, and FRA—was formed to apply scientific and engineering analysis to the problems of train safety and derailment prevention. Much was learned, and in conjunction with the increasing financial health of the industry after deregulation in 1980, the railroad accident rate declined by an order of magnitude. Meanwhile, a parallel project of the railroad and tank car industries began to apply similar analytical approaches to improve tank car safety design. This research and complementary FRA efforts led to a requirement for double shelf couplers on all tank cars used to carry hazardous materials and for the application of head shields and thermal protection to all tank cars used for LPG and anhydrous ammonia transport. Both of these cooperative safety research projects and their successors have continued to the present—producing new results to further prevent derailment and improve tank car integrity.

Given FRA's statutory safety mission and somewhat less clear position as an advocate for the industry, it is no surprise that R&D aimed at safety improvements usually held higher priority in FRA funding than so-called economic research or projects related in any way to marketing or management. Indeed, despite the argument that sponsorship of R&D related to improved railroad reliability and productivity performance was one way that FRA could assist the industry financially without choosing winners and losers (i.e., that research could be conducted neutrally, from a competitive point of view), the Association of American Railroads (AAR) was at times resistant to FRA sponsorship of nonsafety research. In contrast, FRA's greatest R&D successes were the direct result of research under cooperative agreements with AAR.[3] FRA needed the strong technical and logistical support of the private railroads provided through these cooperative agreements. The best examples from the 1970s and 1980s are track–train dynamics and tank car research, and the best examples from the past two decades are grade-crossing warning systems and PTC.

After the passage of the Staggers Act in 1980, FRA turned to the implementation of DOT proposals for dealing with Conrail's huge financial losses and its hoped-for future privatization. The R&D program was scaled back noticeably in the Reagan years. Late in the 1980s, particularly after the awful Conrail–Amtrak collision at Chase, Maryland, in 1987 (16 fatalities), safety regulation focused on drug testing. Other collisions at Hinton, Alberta, Canada, in 1986 (23 fatalities); Ledger, Montana, in 1991 (3 fatalities); and Longview, Washington, in 1993 (5 fatalities) gave impetus to the development of PTC systems. The Hinton wreck was noteworthy in spurring establishment of the Advanced Train Control Systems (ATCS) effort, first in Canada and then in the United States. An important forerunner of current PTC efforts, ATCS sponsored the development of specifications and protocols for ultrahigh-frequency (UHF) radio communications devices and channels approved by the Federal Communications Commission (FCC) for their use. As early as 1984, the National Transportation Safety Board (NTSB) added PTC to its "top 10 most wanted" list for safety enhancements, where it has been ever since. In the late 1990s, FRA joined in a funding collaboration with AAR and Illinois to support R&D in PTC and with other states for work on high-speed rail and demonstrations of better grade-crossing warning and prevention systems.

FRA INSTITUTIONALIZES THE SETTING OF R&D PRIORITIES

A landmark in the history of FRA development of research priorities is a publication from 1980 called *Improving Railroad Technology*, a complete catalog of FRA's R&D projects from that period (*8*). The catalog is divided into three sections: Track, Equipment and Personnel Safety; Railroad Operational Improvements; and Improved Passenger Systems. Section I is the largest, with subsections on equipment safety, track structure and rail dynamics activities, inspection and test support, human factors, and grade crossings. Subsections in Section II address intermodal equipment, classification yards, energy efficiency, and electrification issues—all focused more on efficiency than safety. Section III includes an evaluation of the new AEM-7 electric locomotive for the Northeastern Corridor, tilt-train technology, new passenger vehicle trucks, and interestingly, a subsection on the Railbus—a low-cost (albeit noncompliant with FRA equipment buff-strength standards) way to reintroduce passenger service on underused railroad rights-of-way.

Section I of the 1980 catalog underscores the extent to which R&D priorities had shifted toward support of FRA's safety mission at the end of the previous decade. It documents the activities FRA initiated and sponsored in what were probably its most important contributions to railroad technology improvements over the years—tank car design, track–train dynamics, and rail and wheel flaw detection. Section II reflects the impact of the first (1974) and second (1979) energy crises on R&D priorities; FRA was doing what it could to popularize the understanding of railroad energy efficiency (including by means of intermodal service to attract highway traffic back onto the rails) and the ability of electrification to substitute for petroleum fuel use. Section III was FRA's residual passenger service R&D agenda left from earlier days.

The Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations provides a more recent and comprehensive picture of FRA R&D priorities (*9*). This plan describes FRA's technical activities under two main headings: the Railroad Research and Development Program and the Next Generation High-Speed Rail Technology Demonstration Program. The report also contains an excellent discussion of FRA's vision for intelligent railroad systems, an unenthusiastic update on the congressionally mandated Magnetic Levitation Technology Program, and other program process and information material. The 10-heading breakdown of FRA's RD&D program follows the main thrust of the 1980 catalog, but the new emphases on security, human factors, and train control are noteworthy:

- Railroad Systems Issues: Safety, Security, and Environment;
- Human Factors;
- Rolling Stock and Components;
- Track and Structures;
- Track–Train Interaction;
- Train Control;
- Grade Crossings;
- Hazardous Materials Transportation;
- Train Occupant Protection; and
- R&D Facilities.

The impetus for the Train Occupant Protection heading was the MARC–Amtrak collision near Silver Spring, Maryland, in 1996 (11 fatalities)[4] and the Bourbonnais, Illinois, grade-crossing collision in 1999 (11 fatalities).

THEMES FOR THE APRIL 5 AND 6, 2006, FRA RESEARCH NEEDS WORKSHOP

As noted in the introduction, FRA asked the TRB Committee for Review of the FRA RD&D Programs to provide assistance in developing input for a new Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations (*9*) by engaging stakeholders and customers of the program in a discussion about needed research. As a part of the effort, FRA and TRB scheduled a public workshop on Railroad Research Needs for April 5 and 6, 2006. The review committee organized the workshop around the themes of safety, capacity, and efficiency.

Safety is the main theme running through nearly all FRA R&D work since the 1970s, and its continuing importance needs no justification.

Capacity is a relatively new public concern; it has come to the fore only since the mid-1990s, by which time the Staggers Act regulatory reforms and long-continued economic expansion of the period had effectively used up excess rail line haul capacity from the industry's dark days in earlier decades. For example, the decline of rail passenger service in the postwar period left hundreds of miles of double track where a single line with sidings and CTC provided ample capacity for the available freight. Under the financial strains of the 1980s and early 1990s, railroads also scaled back their systems, by abandoning or spinning off many lighter-density lines to new short-line operators, for example. Capacity shortages also were highlighted by a few examples of "indigestion" following large mergers in the 1990s.

Efficiency has many guises and suggests many avenues for progress in railroading. Mentioned earlier were the close linkages among productivity, profitability, innovation, and investment. The public benefits of Staggers Act deregulation were precisely these, that by allowing market forces to guide the adjustment of industry supply to market demand, firms squeezed out waste and earned sufficient profitability to afford reinvestment. Other efficiency considerations also are important in setting public policy for transportation. One is fuel efficiency; railroads are roughly three times as energy efficient as motor trucks and can be adapted for electric traction—both possible considerations if petroleum resources continue to become more costly to obtain and use. Similarly, railroads are efficient users of capital, especially public capital, which is an important reason for leveling the intermodal competitive playing field. Finally, railroad superiority in providing safe transportation of hazardous commodities is also an aspect of efficiency.

The papers that follow address these themes more comprehensively. They also draw out some important factors related to the trade-offs (positive and negative) naturally encountered in considering priority choices between or among safety, capacity, and efficiency. For example, the papers will point out conflicts among a firm's drive for efficiency running up against FRA's safety rules, or a capacity bottleneck resulting from an efficiency-driven shortage of trained and rested labor. However, readers also will find ample examples of where the three themes reinforce each other—that is, where capacity additions make an operation safer or more efficient, or where a safety investment such as PTC might add line capacity or reduce operating costs. The workshop organizers and sponsors hope these papers stimulate good ideas for improving railroad technology and FRA's support of it.

As noted, discussions at the April 5 and 6 workshop are aimed at helping FRA develop updated R&D priorities for inclusion in its next 5-year strategic RD&D plan.

The program categorization from the 2002 5-year strategic plan (*9*) is a useful starting point for updating FRA R&D priorities, but the review committee believes that the list of topics should be opened to new areas of possibly fruitful exploration. Several examples are suggested as new research categories:

- Materials: Rapid advances in development of new materials—including at the nanoscale (one-billionth of a meter, or the size of small molecules)—may make possible a wide range of applications that affect rail safety and efficient operations.
- Energy: Reemergence of public- and private-sector concerns regarding energy prices, alternative sources, conservation, and emissions may present high-payoff research opportunities.

- Global climate change: Recent hurricanes have focused attention on the possibility that more frequent and damaging storms are related to long-term climate changes. The possibility of a rise in the sea level and more widespread flooding of the kind faced in the St. Louis area in 1993 may stimulate research in the discovery and development of mitigating strategies for the railroads.
- Earthquake and hurricane survivability: Recent damage resulting from earthquakes, hurricanes, and tsunamis may warrant opening a category to support formal investigations of event probabilities, risk management techniques, infrastructure damage mitigation, zoning standards for construction and flood plains, and preparation strategies for public evacuations.

FINAL WORD

Railroads have achieved a remarkable record of technology improvements over their long history, and these improvements have enabled the rise of the rail mode from its beginnings as a primitive pre-industrial curiosity, through development and expansion into the mainstay steam-and-steel economic engine for a century of progress, to today's somewhat less glamorous modern maturity as an energy-efficient, low-polluting, safe, and self-sustaining bedrock of the economy. No one should say that the job is finished, for we are all impatient for additional progress in safety, capacity, and efficiency. Although the enduring enterprise can no doubt continue to contribute to the nation's commercial wealth and social welfare for many decades to come, the success of that endeavor will be highly dependent on continuing improvements in fundamental railroad technology, fair and forward-looking public policy toward the industry, and perhaps—just perhaps—a breakthrough in science or advanced engineering that comes from the ongoing collaboration between the FRA R&D program and the private railroad industry.

NOTES

1. PTC is defined as the integration of data radio communications, accurate geographic positioning, onboard locomotive display of movement authorities, and automatic braking to (*a*) enforce against violation of movement authorities, (*b*) prevent train collisions and speeding, and (*c*) protect track forces operating within their work authorities. PTC may have other benefits, but these are the core functions.
2. In the first half of the 20th century, railroad research was left almost entirely to rail industry suppliers and the federal government did not fund railroad research. Also, there was little funding by individual railroad companies or by industry associations. This began to change in about 1958 when, at the urging of the President of the New York Central Railroad, the Association of American Railroads (AAR) formed a Research and Test Department and provided $1 million to fund research. That funding decreased to $700,000 by 1970, almost all of which was committed to testing for performance and quality assurance of products used by railroads. In 1970, AAR hired a new vice president to head the Research and Test Department. After studying the problems facing the industry and consulting with

operating and technical personnel, the vice president recommended that a program designed to achieve greater stability of the long and heavy trains then being introduced in larger numbers could reduce delays in service and improve safety.

3. No history of this period and topic is complete without noting the leadership of long-time AAR vice president for research and testing, William J. Harris, Jr., who spearheaded the work on both track–train dynamics and flaw detection in steel components. Harris also was instrumental (despite some misgivings) in persuading the AAR to take over "care, custody, and control" of the Pueblo test center after FRA ended a Boeing contract for that responsibility. No other party showed interest, and Harris convinced the AAR that it would be a shame to lose the facility altogether. On his retirement in 1985, Harris received a document of special recognition from FRA. The citation, signed by Federal Railroad Administrator John H. Riley, emphasized the effectiveness of research cooperation between the public and private sectors in addressing such difficult problems as improving safety in the railroad industry. "The personal initiative, energy, and resourcefulness exhibited by Dr. Harris in promoting railroad R&D has proven to be of great benefit to the railroad industry and the American public alike."
4. The Silver Spring collision, like the earlier Alberta, Montana, and Washington wrecks (among others), was also thought to be "PTC-preventable." The worst-ever Amtrak catastrophe, at Bayou Canot, Alabama, in 1993 (near Mobile—47 fatalities), was caused by a barge operating outside its navigable waterway in a fog, and was not PTC-preventable.

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SETTING THE STAGE

Research to Enhance Rail Network Performance

Statement of Workshop Purpose

Mark Yachmetz, *Federal Railroad Administration*

On behalf of Federal Railroad Administrator Joseph H. Boardman, I welcome you to Washington, D.C., during the National Cherry Blossom Festival. For those of you who are from out of town, you have picked one of the best times of the year to visit the nation's capital. And because I am also responsible for oversight of Amtrak, I hope many of you came here by rail.

Thank you for your participation in this 2-day workshop. This workshop is about the future of the rail industry. An essential component of this nation's transportation system, the rail industry hauls more than 40% of our freight. Its leading role in the movement of coal is an essential component of our energy systems and the president's energy policy. Its leading role in the movement of grain is an essential element of our trade policy. And its leading and growing role in moving intermodal containers and commuters is an essential element of any strategy to address the growing highway congestion that threatens the productivity so essential to this nation's economy.

FRA's research program is one component—albeit an important component—of the industry's overall research. It is recognition that we are part of a greater whole that causes FRA to engage the industry, writ large, in discussions about the directions and priorities of FRA research. Frankly, total funding on rail research is small compared with the importance of the rail industry's role in our economy. Thus, we need to make every dollar count.

FRA is committed to a research program focused on practical improvements in rail safety and operations. Over time, such improvements will increase rail safety and efficiency. Initiatives such as the TRB Blue Ribbon Committee on FRA Research, coordination with the research committee of the Association of American Railroads (AAR) and rail research overseas, and this workshop help us maintain our focus.

You are among the most experienced and knowledgeable in the railroad industry. Your input is essential to identifying the key focus areas of our research and development (R&D) for the next several years. The themes for this workshop are what we believe to be the three most significant factors contributing to a successful rail transportation system: safety, capacity, and efficiency. With your help, FRA will identify the specific R&D needs within these three themes and incorporate them into its 5-year R&D strategic plan.

As any good railroad manager would tell you, these three areas are critical to enhancing the performance of the rail network. We need to do well in all three areas to run trains smoothly, safely, and reliably. Similarly, these three areas are not fully independent of one another; they are strongly interconnected and dependent on each other. Doing well in one area often means doing well in the other two areas. For example, using railroad assets more efficiently will translate to improved capacity and enhanced safety, and reducing mechanical, track, or signal failures through better safety management will improve efficiency and increase capacity by reducing service delays caused by accidents or derailments.

However, this interconnection can lead to trade-offs, too. We must ensure that the enhancement of one aspect does not negatively affect other aspects of rail network operation. In such circumstances, research helps us identify optimal levels to balance performance in all areas. I believe that understanding the interrelationships among safety, efficiency, and capacity and focusing our primary research on these three themes will provide much added value to the public and to the railroad industry.

In close cooperation with the railroad industry, FRA has played an important role in R&D for several decades. In recent years, the federal government has consistently provided more than $55 million annually for a wide array of R&D. In collaboration with the industry, FRA has made significant strides in many fronts for innovative research. One example is the pioneering of gage-restraint measurement technology, which has been widely accepted and used by the railroad industry over the past 10 years. FRA also continues to invest in the development of many automated and nondestructive technologies for track inspection. In our opinion, these technologies have great potential to dramatically improve rail safety in the relatively near term, with spin-off benefits to efficiency and capacity.

FRA has built vehicles that can detect track geometry defects, track strength, and failed components (e.g., cracked joint bars) while running at regular track speeds. Many of the developed systems are working elements on research cars and soon will be on the track inspection vehicles of the railroad and FRA's Office of Safety. Similarly, FRA has assisted in the development of wayside systems that can inspect bearing, wheels, axles, and safety appliances of passing trains.

FRA also has made great strides in improving the crashworthiness of both locomotives and commuter cars. On March 23, a successful test was conducted at the Transportation Technology Center in Pueblo, Colorado, that showed how research can lead to better designs that greatly improve the safety of occupants during a collision.

FRA also has made significant investment in the development of advanced train control systems and the deployment of the Nationwide Differential Global Positioning System (GPS) system. Whereas positive train control (PTC) systems have not yet been widely deployed, activities in developing these systems and arranging demonstrations of the technology have accelerated significantly in recent years.

In cooperation with the Railroad Research Foundation, AAR committees, and universities, progress has been made in developing wireless communication technology.

This technology not only is critical in train control technology but also is required for many other new railroad management initiatives that will improve capacity and efficiency.

Other areas in which FRA has made significant progress include hazardous materials transportation safety, smart train technology, and human factors and grade-crossing safety, to name a few.

FRA also has developed many analytical tools that allow us to better evaluate derailment risk, track–train interaction, and the human–machine interface. Of course, these projects were all driven by the need to improve railroad safety. In fact, safety is the main theme running through nearly all of FRA R&D work since the 1970s. As a federal agency, the need to focus on public safety was obvious. Safety will continue to be an important theme for most future R&D work. However, we also recognize the need for and are interested in doing R&D that leads to capacity and efficiency enhancement. Capacity and efficiency are key to improving transportation mobility, one of Transportation Secretary Norman Y. Mineta's strategic goals.

Capacity becomes ever more important as fuel costs rise and more freight moves from the highways to the railroad. Many government officials are increasingly looking at the railroad option to provide an alternative venue to meet the growing demands for freight and passenger mobility. In many cases, the construction of new rail lines is cost prohibitive, thereby increasing demand on existing lines. To accommodate new traffic on existing lines, new technologies and research are needed to guide safe and efficient implementations. The opportunity is the greatest in the existing dark (unsignaled) territories.

Although railroad still presents the most efficient mode for the ground-based shipment of freight across the United States, there is always room for improvement. Improved efficiency will make the railroad more profitable and will improve the United States' ability to compete in an increasingly global economy. In this era of anticipated continued high-energy prices due to world demand, fuel efficiency is an important consideration. We should think about how we can improve this efficiency even more to make the United States less dependent on outside energy sources.

Your efforts over the next 2 days will help FRA develop a new and more responsive 5-year R&D plan—one that can best use our R&D resources. By focusing our workshop on safety, capacity, and efficiency, we hope to better identify research needs to ensure that FRA is on the right track for years to come.

And with that pun, I will close. Thank you again for your participation.

CAPACITY

CAPACITY

Railroad Capacity Issues

James McClellan, *Woodside Consulting Group*

Capacity, or rather the lack thereof, is getting a lot of attention in transportation circles these days. Urban highways are increasingly congested, some important ports have bottlenecks, and congestion even has returned to many hub airports.

Especially in the West, railroads have absorbed huge increases in both train miles and ton-miles in recent years. But many railroad mainlines are now at or near capacity. Railroads have responded by adding capacity as well as shedding some low-margin traffic to make room for higher-margin business.

RAILROAD CAPACITY

It's a National Transportation Issue

A railroad capacity problem would be of minor national importance were alternative modes able to handle substantial growth. But the reality is that highway construction is not keeping up with the growth in demand largely because of financing, environmental, and community impact issues.

Many public officials look to the railroads to provide a safety valve for a rising tide of freight traffic. If railroads obtain the capacity to handle growth, some pressure will be taken off the highway network. And if not, then highway congestion will worsen considerably, and the cost and reliability of freight transportation will suffer.

It's a Freight and Passenger Issue

Railroads play a minor role in the movement of people outside of some well-defined urban areas such as New York; Boston, Massachusetts; Chicago, Illinois; and Los Angeles, California. However, the public interest in expanding commuter rail and some intercity rail services as an alternative to building more highways is increasing. Given constraints in rail capacity, passenger services can be expanded little without adding substantial new capacity or severely limiting the ability of railroads to handle freight traffic.

Even today, the efficient and reliable movement of freight is undermined by passenger train congestion in such areas as Chicago and the New York–Washington, D.C., corridor. The simple fact is that delaying a stack train carrying 200 truckloads of traffic is a bad transportation strategy. The railroads understand this and will not agree to add more passenger service unless they can be assured that freight service will not be negatively affected by such expansion.

CAPACITY: A COMPLEX ISSUE

Capacity is created (or destroyed) by a host of interrelated factors. Although we tend to think of capacity as an infrastructure issue, rolling stock, motive power, employees, and operating strategies (e.g., size, speed, and timing of trains) are all part of the equation.

In a complex network business such as railroading, all of these factors are related. Underpowered trains wreak havoc with track capacity. Too many trains running at different speeds have the same impact (which is why some railroads are taking a harder line about faster schedules for UPS and other premium intermodal customers). If yards are congested, then trains are held on line of road, which reduces line-of-road capacity and "burns" crew availability. And so it goes.

The key capacity drivers—infrastructure, motive power, crews, and operating strategies—must be handled holistically. The reality is that, much of the time, plenty of capacity is available on most of the track network (just as much of the highway network has capacity many hours of the day). However, around urban areas, key junctions, and other choke points, congestion can worsen during certain parts of the day or on certain days of the week.

Building more tracks seems a natural solution but may not be the best alternative. A fixed plant is so called for a reason; once in place, it is costly to move the resources elsewhere. Thus, a different operating strategy (e.g., changing schedules or powering up some or all trains) is often a less costly and less risky solution; locomotives can be moved around, but track cannot.

HISTORICAL PERSPECTIVE

Railroads have been dealing with capacity issues almost since their inception. It has been a story of feast or famine, and the financial consequences have been profound.

Railroads were usually built ahead of demand, and that demand often failed to materialize. Numerous bankruptcies occurred throughout the 19th century; overcapacity and flawed financial structures were the root causes.

In World War I, the issue was congestion and too little capacity; the 1920s saw a relative balance between capacity and traffic levels. During the Great Depression, capacity was too great, and the financial impact was disastrous. World War II (WWII) created massive congestion, and all the surplus capacity proved invaluable.

After WWII, the East and Midwest suffered from massive overcapacity as passenger and freight traffic fled to the highway. Meanwhile, in the Southeast and the West, a growing economic base generated more rail freight traffic despite a loss of market share. Railroads in both of those regions had limited capacity; most of the lines had but one track. Technology, in the form of dieselization and automated dispatching, saved the day.

In the 1970s, at the time much of the Northeastern and Midwestern network was being rationalized, Burlington Northern (BN) was coping with a massive increase in coal traffic. New lines were built, and thousands of miles of branch line track were upgraded to mainline status. The cost of that new capacity nearly destroyed the financial viability of BN.

In the past decade, a surge in intermodal traffic has pushed capacity limits on the mainline network both east and west of the Mississippi River. All railroads are now spending substantial amounts to remove choke points.

VITAL ROLE OF TECHNOLOGY IN INCREASING RAILROAD CAPACITY

The history of railroading has been one of continuous capacity enhancement through technological innovation. Trains have grown longer and heavier, locomotives ever more powerful; freight cars carry larger loads; track structures are more robust and require less outage for maintenance; and control systems are increasingly sophisticated.

In the past, technology has been introduced at a relatively slow pace. Dieselization required more than a decade to build the locomotives and create the supporting shops and fueling facilities. Heavier cars required substantial upgrades to the track structure infrastructure (although some railroads tried to avoid that reality), and the introduction of double-stacked container cars required modifications to clearances on thousands of route miles.

Technology will play a vital role in solving today's capacity challenges, but most of the technological fixes will require time and capital. The rail system is simply so extensive (measured in track miles or number of vehicles) and most changes so costly that adding capacity is constrained by both physical and financial constraints.

SAFE RAILROAD ENHANCES CAPACITY

A high-capacity, busy mainline simply cannot tolerate any outages. Even planned downtime for maintenance can wreak havoc with both schedule reliability and capacity.

An accident—by definition, an unplanned outage—worsens the situation. Thus, a serious derailment or grade-crossing accident can affect operations for hours or even days, blocking mainlines and congesting yards. Crews outlaw and must be relieved without the freight being moved; soon, crews are in short supply. Operations can get very ugly, very fast.

The introduction of the 100-ton freight car caused the abandonment of thousands of miles of feeder lines, primarily in the Midwest. The track could not handle the larger cars, and traffic volumes did not justify the required investment. Thus, a capacity-enhancing strategy had the unintended consequence of removing substantial track capacity.

Remember, railroads often have no available alternative routes—especially in the West—and the alternate routes that exist probably are busy as well. Therefore, in the event of an unplanned outage, hundreds of trains can be delayed, with all that means in terms of locomotive and crew turns.

HIGH-QUALITY, RELIABLE SERVICE REQUIRES SUFFICIENT CAPACITY

Stuff happens; after all, railroading is an "outdoor sport." So, when a high-capacity mainline congeals for whatever reason, service reliability suffers. The solution is to have some level of redundancy.

Americans marvel at the precision of the German, French, and Swiss passenger rail networks. As anyone who has ridden trains in those countries knows, much infrastructure and equipment support each network: multiple tracks, multiple routes, and multiple cars and engines sitting around any major terminal. All that investment requires money to supply and maintain.

Such is the central economic issue: How much redundancy is needed for reliable service, and just how much will the market pay for reliable service? Recent experience suggests that railroads with dependable service can charge more for their product.

CAPACITY IS COSTLY

Capacity—track, yards, locomotives, and crews—is expensive. Adding one road locomotive to handle more business is much more costly than just the initial purchase price of almost $2 million; it also needs shops and personnel to maintain it, creating a significant life-cycle cost.

A siding with centralized traffic control (CTC) costs more than $10 million , and even more if substantial grading is required. As for a locomotive, the initial investment must be supported by an expanded maintenance-of-way budget, including additional personnel. Rolling stock presents a similar capital and maintenance scenario.

Trained crews represent a major investment as well. It takes months to hire, train, and qualify entry-level train and engine service personnel. For that time period, each new hire is an operating cost that significantly affects both profits and the operating ratio. All the while, pay and benefit costs must be met, not to mention the costs of recruiting and training.

Whether a capacity increase involves more cars, locomotives, track, crews, or a combination thereof, the economic cost is substantial, and such costs always require finding the necessary financing.

Railroading is a careful balancing act, and compromises (in service quality, operating efficiency, and financial returns) are made constantly. If the capacity of cars, locomotives, crews, or any combination is inadequate, then traffic and revenues decrease while operating costs increase. However, too much capacity (again, in terms of track, terminals, cars, locomotives, and crews) means that financial returns decline and the availability of capital becomes more expensive. So, management is in a constant struggle to create just-in-time capacity—that is, having the resources in place when needed, not 6 months sooner or later.

ALL CAPACITY SOLUTIONS REQUIRE LONG LEAD TIMES

The balancing act is made more difficult because most capacity “fixes” require a long lead time. Building a new intermodal terminal is a 5-year proposition, even without significant environmental and community impact issues. In a tight market, obtaining a new locomotive takes a year and a freight car a year or more. Hiring and training a locomotive engineer takes a year.

Simply adding a siding to an existing mainline (assuming that the right-of-way is available) takes 6 to 18 months from the decision to build.

VARIOUS WAYS TO ADDRESS CAPACITY CHALLENGES

The strategies include but are not limited to the following kinds of actions.

Use Existing Resources More Efficiently

The operating plan can be modified to make better use of existing resources; all railroads are pursuing such changes. Changing operating strategies often involves a partnership with customers. Customers need to understand the costs of peak service and special handling; railroads are moving toward rates that are appropriate to a capacity-constrained universe. Most of these changes involve a difficult balancing act, and no company wants to antagonize long-term base customers to the extent that they will seek other alternatives.

Add Resources

Capacity can be added to handle the increased levels of business. But capacity is both costly and potentially risky, so railroads want to make reasonably certain that the market will support capacity increases over the long term. Any capacity-enhancing project (fixed plant, locomotives, or cars) must be compared with all of the other demands on corporate capital, and the returns must be attractive. Furthermore, all investments must be consistent with a company’s ability to raise capital. However worthy a capacity project might be, in the end, it must improve financial returns.

Shed Traffic

A railway may choose to address a capacity issue by effectively demarketing certain low-margin traffic or traffic that creates extraordinary congestion. For example, an occasional rail user on a busy mainline may create so much delay to road trains that the only solutions are to build a siding to avoid interference or simply to demarket the traffic.

By the way, this reason is why commuter rail projects can be so contentious. By creating delays on the final mile of a transportation movement, a commuter train operating, say, 30 mi can undermine the reliability of an intermodal stack train operating 1,000 mi or more.

Lower Service Standards

A railway may simply accept lower standards of service during peak hours or for some customers. A strategy of poorer service or higher rates during peak times is a de facto reality with all transportation modes today.

All of these strategies and other solutions are used to address capacity issues; the trick is to find the right balance that will meet the long-term goals of the private sector (which may be entirely different from a solution desired by the public sector). The reality is that railroads answer primarily to financial interests, and whereas regulators can impose some limitations, restrictions that dry up the availability of capital simply will result in constraints on new rail capacity investments, or even rationalization of current facilities, in the future.

WALL STREET IS MORE TOLERANT OF CAPITAL EXPENDITURES

The private sector offers some good news. For decades, a railroad that followed the "build it and they will come" strategy would evoke a steely look from the financial community. Railroads were not earning their cost of capital, so skepticism that growing the business was good for the financial well-being of the enterprise was justifiable. Tight controls on capital expenditures coupled with a buyback of shares were seen as the right financial strategy.

Now, Wall Street is more accepting of a growth strategy. Several major railroads have proven that good service leads to growth and higher margins. Capital investment needed to support service quality and increased traffic volume is now seen as a good use of capital. Railroads still must prove that they are using capital wisely, but as long as they continue to produce good financial returns, Wall Street will be supportive.

WHERE CAN RESEARCH AND DEVELOPMENT HELP?

This issue is central to this workshop. The need for increased capacity is obvious and growing. The financial constraints, whether imposed by the private sector or the public sector, are substantial; not enough money is available to do all the things that the railway commercial and operating folks would like to do. Customers are pressing for more capacity and will pay, but only if they are convinced that the higher rates will improve service reliability within a reasonable time frame. Both customers and Wall Street will reject technology solutions that smack of "gold plating" or in which the benefits will be achieved only at some point far in the future.

The railroads are at a crossroads. If they step up and solve their service quality and capacity challenges, then they will be able to assume a greater role in the transportation arena. If they cannot, then the world will move on to other solutions.

The challenge to the research and development community is to deliver solutions that can be implemented rapidly and at minimal cost. We should never ignore research paths that promise a home run, but right now, many singles are needed.

The convergence of need with financial limitations means that finding timely, low-cost ways to add capacity is absolutely critical.

CAPACITY

Freight Rail Perspective on Capacity Issues

Summary of Remarks

Charles W. “Wick” Moorman, *Norfolk Southern Corporation*

Clearly, the changes in the transportation marketplace observed in late 2003 have continued. Trucking capacity remains constrained. Higher fuel prices have driven up the costs of trucks while again underlining the efficiency advantages of trains. Demand for rail services continues to grow. Intermodal leads the way, as more and more international traffic flows into all U.S. coasts.

At the same time, higher natural gas prices increased demand for utility coal, giving us higher volumes and more pricing power. In general merchandise as well, higher demand for our transportation services, along with our continuing efforts to improve service, have provided growth opportunities.

It is a good time to be in the railroad business, as revenues reflect. The financial markets also have noticed, with rails considerably outperforming the Standard & Poor’s averages. Obviously, the state of the industry is robust, and we have every reason to be optimistic about the future. At the same time, we continue to face challenges, some driven by our own success. They include capacity constraints, the need to improve service reliability and consistency, the threat of re-regulation, and the handling of highly hazardous materials.

In my time with you, I explore one of those big challenges—the capacity issue—and how our research initiatives can be designed to help create solutions.

All sectors of transportation are dealing with capacity challenges. Total highway traffic has more than doubled in the past 20 years, with virtually no increase in capacity. Air travel is projected to triple over the next 20 years.

Railroads face our own supply–demand issues. The U.S. Department of Transportation projects a 55% increase in rail freight traffic demand by 2020 compared with 2000 levels. The good news generally is that railroads have demonstrated they can handle record volumes of traffic safely and at reasonably good service levels. Of course, we’re all working to raise the service standard. At the same time, we are coming up with creative ways as an industry to take on increased volume.

Fortunately, transportation policy makers at the federal, state, and local levels have seen the public benefits of a strong private rail network. That thinking is reflected in legislative initiatives that would amend the tax code to provide incentives for railroads. This might be an investment tax credit for new rail lines and other similar investments, provision for more liberal expensing of investments, or some combination of these approaches.

Public–private partnerships have emerged as the new paradigm for funding transportation improvements that not only increase capacity but also strengthen the nation's commerce and provide significant competitive benefits and economic development opportunities for communities. We have a clear way of viewing this: The public pays for public benefits, and we pay for benefits accruing to the railroad.

The best public–private partnership example in the East is the Heartland Corridor, a multistate rail-improvement project that will improve the increasing flow of consumer goods between the East Coast and Chicago. These types of programs produce public benefits by reducing rail and motorist congestion, improving passenger rail service, enhancing public safety, stimulating economic development, and improving air quality.

Another high-profile project is the Chicago Region Environmental and Transportation Efficiency Program (CREATE), a partnership that includes the state of Illinois, the city of Chicago, Metra, and the nation's freight railroads. CREATE is one example of how public–private partnerships can improve the nation's rail infrastructure. It demonstrates how capacity needs can be addressed for passenger and freight traffic. Shortly, you will hear from Phil Pagano, who was one of the first visionaries who pushed the railroads and the public sector to see the magnitude of CREATE's rail improvements to the region and the nation.

Given the project's importance and level of public support, we were disappointed in the federal allocation for CREATE. However, it is a starting point, and we are working on a first phase of CREATE to make what we can make happen with the funds available, knowing we will need to return to Congress for additional funding down the road.

Chicago today remains the busiest rail gateway in the United States. One-third of the nation's freight rail traffic moves to or through Chicago. Over the next 20 years, demand for freight rail service in Chicago is expected to nearly double. CREATE will enable Chicago to keep up with the demand. This Chicago infrastructure is important to the nation, and we all need to do our best to see this project through to the end.

We've seen other joint ventures to increase capacity. Kansas City Southern and Norfolk Southern (NS) are working together to improve service on the Meridian Speedway between Meridian, Mississippi, and Shreveport, Louisiana. In this case, NS is paying for capacity improvements on another railroad.

Moving forward, capital investments to handle increased demand are critical to our economy. This brings to mind another industry challenge that is closely related to creating capacity: the need to earn our cost of capital.

Rail is the most capital-intensive industry by a huge margin. Since 1980, railroads have invested nearly $360 billion to maintain and improve infrastructure and equipment. For more than 20 years, the story was that railroads did not return their cost of capital. However, this situation has generally improved. Cost of capital has remained fairly level for the past 15 years, whereas the average rate of return on net investment—which had been falling for decades—has been rising.

Several railroads earned their cost of capital last year. For some, it was the first time ever. The new story is that the industry is moving in the right direction. But we cannot afford to take a deep breath. We need to earn our cost of capital over the long term. It's a new world. We are a growth industry, and if we are to continue to meet the demands of our customers and the expectations of the public, then this industry will need a long and sustained period when returns are maintained so that investment can be robust.

It is not a stretch to say that the technology of the future is here today. Our imperative is to make sure it continues to get the resources required to develop it into practical and reliable applications for the transportation industry. For example, everyone is working on some form of positive train control system, which combine data communications, positioning systems, and onboard computers tied to a train's braking systems to enforce speed and operating limits automatically. Such a system would enhance operating efficiency and safety while enabling train operation by a single person. This kind of advance also has implications for capacity because people would be freed up to operate additional trains, and trains could run closer together.

The list of capacity-related research initiatives is long, but I'll mention a few. The priority for us as an industry is to keep the momentum going in these areas so we can harness their anticipated benefits—as well as their as-yet-unknown pleasant surprises—as quickly and as fully as possible.

Ongoing issues regarding the regulation of radio frequencies point to the need for new developments in wireless communications systems and radio communications technology.

Research related to reliability and performance of the transportation network, including systems such as unified train control, has big implications for capacity. Every mile-per-hour difference in average train speed on the NS network equates to 100 locomotives. Train speed also affects car hire costs.

We must research the development of distribution systems to improve locomotive utilization. We must bring locomotive maintenance to a higher level. Health monitoring and remote diagnostics are good first steps. To achieve really significant advances in reliability, we must develop predictive systems based on science such as artificial intelligence. As freight cars get heavier and traffic increases, we should develop freight car trucks that will not prematurely wear out our track structure and rail. We must achieve a performance that equals tangent track forces in curves. Other areas of needed short- and long-term research are (*a*) network management tools for the development and improvement of dispatch systems and (*b*) tactical and strategic models for optimizing train schedules. We must refine our ability to operate different types of trains over the same territory—from hotshot intermodal trains to time-sensitive coal and grain unit trains.

We also need continued research and development on maintenance-of-way work equipment that can be deployed more quickly with less disruption to the network.

We must continue to develop capacity and technology while avoiding unnecessary new regulations that would constrain our mission as common carriers. Our future looks good.

CAPACITY

Railroad Capacity from a Commuter Rail Perspective

Summary of Remarks

Philip A. Pagano, *Metra*

Metra serves metropolitan Chicago and ranks as the second-largest commuter rail operation in the nation, behind only New York's Long Island Railway. Officially designated the Northeast Illinois Regional Commuter Railroad Corporation, Metra was formed in 1984 as an independent agency overseeing commuter rail operations in Chicago's six-county region. Systemwide, Metra runs 692 trains a day on 11 lines, and only one of those lines is used exclusively by Metra's commuter rail operation.

On all other Metra routes, Metra trains share the rails with its freight partners and, in many cases, run across other freight lines, making capacity a buzzword. Each day in Chicago, Metra runs close to 700 trains on these rails while major freight carriers such as Union Pacific, Burlington Northern Santa Fe Railway, Canadian National, and others throw in another 500 trains. With each passing year, these numbers are not decreasing—on the freight side or the commuter side.

With Chicago's population growing at record rates, there is no turning back on the advancement of commuter rail. That's why Metra has an aggressive vision for the future. Key to that future are track and signal updates on two of our existing lines, projects specifically designed to increase the routes' capacity. Both are Union Pacific projects, and both stand to allow more commuter trains to cover their respective areas and further reduce congestion created by freight trains continually tangled in Chicago's railway spaghetti bowl.

Under the latest federal transportation funding package, Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, Metra also is aggressively working on two new lines that will foster its goal of meeting new commuter patterns, primarily suburb-to-suburb travel and the increasingly popular reverse commute. In the southern part of the Chicago metropolis, Metra plans to launch the SouthEast Service, a new line between Chicago and Balmoral Park in Will County. It will be the first new commuter line to open since 1996 and only the second new route in more than half a century. The other project is the Suburban Transit Access Route Line, which will link the so-called spokes in Metra's system, creating the first-of-its-kind suburb-to-suburb commuter rail service. The key to both projects is that they depend heavily on cooperation with Metra's freight partners, because each will run over existing freight track.

RESEARCH TO ENHANCE RAIL NETWORK PERFORMANCE

Chicago's rail infrastructure dates back 150 years and isn't getting any younger. With freight traffic growing and demand for commuter service showing no signs of slowing, all players in the railroad industry are coming together to plan for the future. Over the next 20 years, freight volume in Chicago will increase by roughly 20%.

In our region, through a partnership of local railroads and transportation agencies, the Chicago Region Environmental and Transportation Efficiency (CREATE) plan has emerged as the vision for addressing capacity problems. Key to this $1.5 billion upgrade are the construction of 25 road–rail separations, six passenger–freight rail flyovers, 50 mi of new track, and 364 new switches and the automation of 14 interlockings.

With CREATE and Metra's commuter rail New Starts, railroad has an exciting future in Chicago, one that is key to the city and region's economic vitality.

SAFETY

SAFETY

Safety, Service, and Sustainable Growth

Technology and People Working Together

Jo Strang and Grady C. Cothen, Jr., *Federal Railroad Administration*

[U.S. DOT] Strategic Objectives

- Safety: Enhance public health and safety by working toward the elimination of transportation-related deaths and injuries.
- Mobility: Advance accessible, efficient, intermodal transportation for the movement of people and goods.
- Global connectivity: Facilitate a more efficient domestic and global transportation system that enables economic growth and development.
- Environmental stewardship: Promote transportation solutions that enhance communities and protect the natural and built environment.
- Security: Balance homeland and national security transportation requirements with the mobility needs of the nation for personal travel and commerce.

We can identify and help build projects that reduce congestion, and we have the ability to design a public policy that makes congestion-reducing infrastructure easier to build. So in addition to continuing our hard work on the strategic objectives announced in 2003 and other important transportation measures, we have determined that reducing major congestion chokepoints throughout America should be a major DOT priority moving forward.

—Maria Cino, Deputy Secretary of Transportation

Transportation Secretary Norman Y. Mineta has asked us to envision safer, simpler, smarter transportation solutions. At every turn, we see the interrelationships among factors such as quality of service, efficiency, environmental protection, and safety across transportation modes. By stepping back and gaining a clearer view of the larger whole, we come to understand that each element of our transportation system is stressed and that this condition is rife with pitfalls and opportunities.

Solutions that are safer, simpler, and smarter will have the quality of elegance. Elegance suggests both beauty and absence of waste. We start with safety because the absence of safety is waste. Quite apart from the intrinsic values that we recognize as individuals, unnecessary loss of life and harm to people, which in many cases will stress our insurance and public welfare systems for decades after the accident, are economically foolish and, for good reason, are poorly tolerated by the electorate. Damage to property and disruption of the transportation system are also wasteful and in sharp conflict with efficiency and quality of service. Add disruption to existing congestion, and economic waste grows to dimensions and in ways that are difficult to measure.

Elegant solutions will keep people and goods mobile and keep costs down by avoiding mishaps and focusing each mode of transportation on what it does best.

So, what is our role in this process of intermodal progress through elegant solutions, and how does this symposium fit in?

The Federal Railroad Administration (FRA) is a modal administration within the U.S. Department of Transportation (DOT), created by the Department of Transportation Act of 1966 [49 U.S.C. 103, Section 3 (e)(1)]. The purpose of FRA is to promulgate and enforce rail safety regulations, administer railroad assistance programs, conduct research and development (R&D) in support of improved railroad safety and national transportation policy, provide for the rehabilitation of the Northeast Corridor rail passenger service, and consolidate government support for rail transportation activities. Today, FRA is 1 of 10 agencies within DOT concerned with intermodal transportation. It operates through seven offices under the administrator and deputy administrator.

The Office of Railroad Development plays a vital role in developing and testing new technology to advance science and engineering to improve technology for railroad safety. Some of FRA's most important activities are the research, development, and test programs that have led to remarkable improvements in technology and safety. FRA has worked on a wide range of projects over the years, covering such topics as track, vehicle track interaction, passenger equipment, locomotives, freight cars, signal- and train-control systems, hazardous materials transportation, grade crossings, human factors and operating practices, and positive train control (PTC).

The issue at hand is the planning and execution of the next 5-year research, development, and demonstration plan; the DOT strategic goal is to enhance public safety and health by working toward the elimination of transportation-related deaths and injuries. The current state of railroad safety is good, but it can be better. We have also been tasked with reducing congestion while improving safety.

HIGHWAY–RAIL CROSSING SAFETY

For FRA, the area of greatest interest for future safety improvement is smoothing the flow of traffic at intermodal intersections. Although grade crossing collisions are no longer the single largest cause of fatalities associated with rail operations, they are a strong second; history suggests that this area is responsive to countermeasures. Failure to fashion even more elegant countermeasures will result in a rising toll of deaths and injuries because train and motor vehicle counts, as well as pedestrian exposure, continue to grow. Although investments in crossing warning systems and other conventional safety improvements at crossings will continue to be necessary to drive the absolute numbers down, and although general highway countermeasures will continue to contribute to good outcomes, we can do many things to further reduce risk (Figure 1).

In the short term, we can take numerous actions that support the strategies set forth in the Secretary's 2004 Action Plan for Highway–Rail Grade Crossing Safety. For instance, we can

- Document and perfect research and standards that enrich options for basic improvements in engineering at grade crossings (e.g., more extensive interconnection of warning systems, guidance for elimination of visual clutter that can defeat motorist compliance);
- Target available funding at crossings that have the greatest risk by fashioning models that include severity as well as frequency measures in our priority determination methods; and
- Focus sharply on strategies to address private crossings, the true outcasts of the crossing safety debate.

Over the long term, we can

- Build public–private partnerships that will simplify our transportation system through additional grade separations and consolidation of traffic flows and
- Marry intelligent railroad systems with intelligent highway systems to provide better and more affordable warning that reaches into the motor vehicle itself.

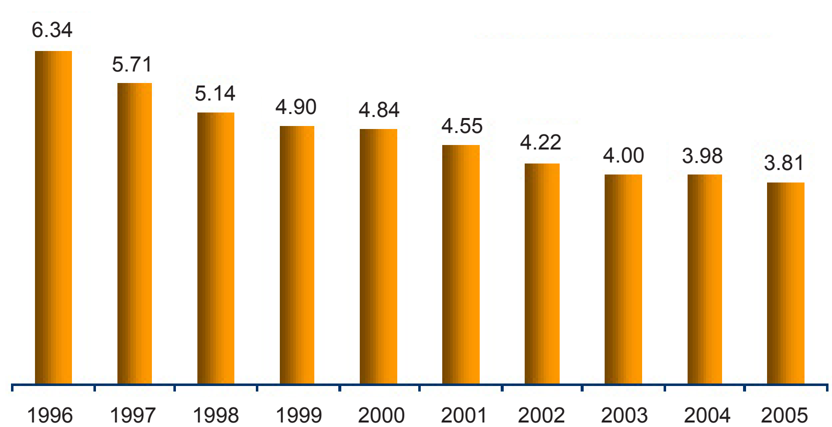
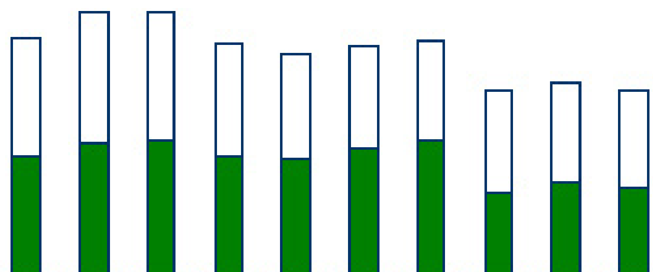


FIGURE 1 Highway–rail incidents per million train-miles, 1996 to 2005. (Data for 2003 to 2005 are preliminary.)

The questions are how much emphasis to give to each of these areas and which tools to choose. Prior research into effectiveness of available countermeasures has been useful but not always transparent or comparable with other work. It is tempting to explore the widest possible range of options—among those options new hardware and software will always be preferred because we have an unlimited appetite for technology. The human dimensions of this issue, however, are fundamental; as we go forward, we need to better understand why motorists, in particular, behave as they do. Then we must make the results of research accessible to those who deliver programs

TRESPASSER CASUALTIES

If a broad base of information and a wide range of strategies support progress toward eliminating grade-crossing casualties, then the contrast posed by trespasser events is stark. We know where these events occur, by state and county; we know that this is not one problem but many; and that is about all that we know (Figure 2).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Injuries	474	516	513	445	414	404	395	399	404	386
Fatalities	471	533	536	479	463	511	540	334	368	355

FIGURE 2 Trespasser casualties, 1996 to 2005.
(Data for 2003 to 2005 are preliminary.)

As if this situation were not bad enough, congressional support for addressing this issue at the federal level has been lukewarm to outright hostile.

FRA is currently conducting a trespasser demographic study that may assist us in getting some traction on this issue, and we are open to suggestions for innovative approaches. FRA's highway–rail grade crossing managers continue to attack pockets of known trespassing through educational outreach and energizing law enforcement. What else must we do, now and in the future?

PASSENGER SAFETY

During the late 1980s and early 1990s, FRA funded extensive research into high-speed ground transportation safety. These efforts provided the technical foundation for a new generation of high-speed service in the Northeast Corridor and also yielded basic knowledge that is generally applicable to passenger rail safety. Since 1994, we have focused on the following:

- Vehicle crashworthiness, including crash energy management;
- Occupant protection through better secured fixtures, compartmentalization, and other means of occupant restraint in collisions; and
- Improved emergency preparedness and emergency systems, including better fire safety evaluation techniques, so that events are more survivable.

We also have maintained a strong program addressing track–vehicle interaction limits, helping to diagnose the low-speed derailment tendencies of some passenger car trucks on the one hand and supporting higher cant deficiencies for improved trip times on the other.

This research has yielded a large body of engineering knowledge and practical tools that can be used to suggest desirable vehicle characteristics and to evaluate equipment offered in the marketplace. Attention to emergency preparedness has resulted in the identification of new approaches currently in place in the passenger fleet.

The products of research have been used in the development of the revised Track Safety Standards, the Passenger Equipment Safety Standards, the Passenger Train Emergency Preparedness rule, and the American Public Transportation Association's Manual of Standards and Recommended Practices (PRESS Standards). Most recently, they also have been used to provide the foundation of technical specifications addressing crash energy management for Metrolink's passenger car procurement, which may help set the standard for the commuter rail industry going forward. Forensic investigation of the mechanisms and nature of passenger injuries has provided data for future work to make passenger car interiors more friendly in the event of a derailment or collision.

On March 23, 2006, we successfully completed a full-scale crash test simulating a head-on collision between two passenger trains at a closing speed of approximately 30.8 mph (target: 32 mph). A cab car led the striking train. The cab car and each passenger coach were equipped with crush zones and shear-back couplers with energy absorbers. In contrast to a similar test of conventional equipment (which led to an override of the locomotive by the cab car and destruction of the cab car operator's compartment and approximately 10 rows of seating), the operator's compartment and the entire occupied volume of the cab and coach cars were preserved. The train remained on track and in line, and significant additional capacity remained in the energy-absorbing components of the crash energy management system. The test also successfully demonstrated a prototype table between facing seats, showing that permitting crush of that fixture can prevent fatal abdominal injuries to seated passengers from the crash pulse (Figure 3).

Future work will include additional tests to explore other accident scenarios, finalization of dynamic criteria for cab car end structures, exploration of strategies to bet-

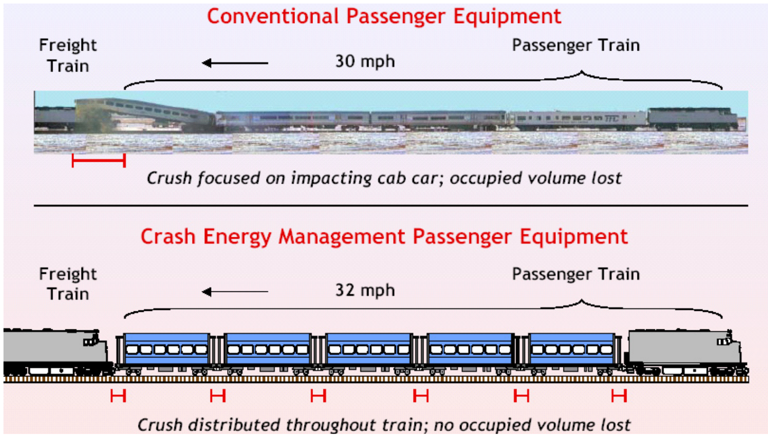


FIGURE 3 Train-to-train tests.

ter protect the train's operator, and refinement of sled test procedures for seat qualification.

Furthermore, as we look to the future, we must know more about where investments in safety technology and procedures can make the biggest difference. One thing is clear: Poorly engineered highway–rail crossings and insecure rights-of-way are the enemies of passenger rail service. About one-third of Amtrak's human and property losses result from collisions at crossings, and events at such places as Portage, Indiana, in 1998 and Glendale, California, in 2000 show the vulnerability of passenger service to influences from the larger community. Resources are scarce in relation to needs, so we must choose wisely where to invest.

TRAIN ACCIDENTS AND EMPLOYEE CASUALTIES

FRA's roots go back to the Safety Appliance Acts of 1893, which initiated a series of actions designed to end massive loss of life among railroad train and engine personnel. FRA investigates every employee fatality and closely follows the progress of carrier injury reduction programs, which have shown striking successes that continue to the present day (Figure 4).

Through efforts such as the Switching Operations Fatality Analysis emphasis program, inspections to ensure that freight cars and locomotives are safe work places, and enforcement of key operating and safety rules, FRA seeks to contribute in part to this salutary record. FRA must continue practical research that helps to explain why well-trained personnel make mistakes that lead to discipline and how work conditions can be adjusted to make them less likely.

Train accidents are a cause of concern because they can threaten the safety of crewmembers and other people in the vicinity of the event. They also result in destruction

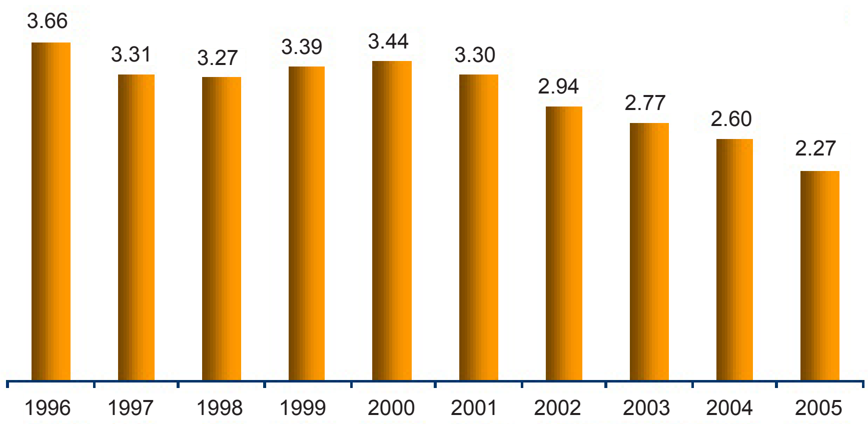


FIGURE 4 Employee-on-duty casualties per 200,000 hours worked, 1996 to 2005. (Data for 2003 to 2005 are preliminary.)

of property and disruption of rail service. Most large-quantity releases of hazardous materials in the rail mode result from train accidents.

Over the past two decades, significant strides have been made in reducing equipment-caused train accidents. However, since an initial dramatic drop in train accidents following enactment of the 4R Act of 1976 and the Staggers Rail Act of 1980, train accident rates have largely stagnated. In recent years, absolute numbers of these events have risen, both in the yards and on the main line. That we have failed to do better despite many breakthroughs in track and equipment components, vehicle qualification programs, defect-detection technologies, and other fields speaks to the need to seriously reexamine how well we are managing our assets and urges caution with respect to placing further stress on an already overburdened infrastructure.

There is much good news, of course. The industry has made significant headway in preventing equipment-caused accidents, and major train accidents caused by loss of braking control are largely a thing of the past (thanks to two-way end-of-train telemetry). However, human factor– and track-related train accidents have been resistant to reduction (Figure 5).

Although train accident rates may be at historic lows, the public, the U.S. Congress, and the fluidity of our transportation system demand even better. The conditions that threaten small communities with hazardous material spills also make freight railroading and emergency response a concern. We need look no further than the Powder River Basin in Wyoming to see that safety and capacity are joined at the hip.

The Secretary's National Rail Safety Action Plan (April 2005) outlines numerous tactical steps we are taking to attack the causes of accidents related to human factors and tracks. However, more will be required, and research and demonstration must be a foun-

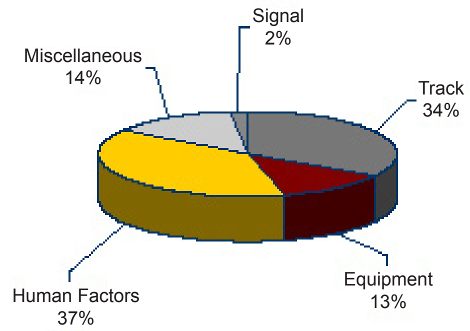


FIGURE 5 Industry overview: train accident cause categories, 2001 to 2005.
(Data for 2003 to 2005 are preliminary.)

dation of that effort. Again, focus on human factors and track and structures seems to be indicated (Figure 6).

HUMAN FACTORS

FRA has been focusing on the underlying causes of human factor–related train accidents and personal injuries. We will shortly publish a report to Congress on remote control locomotives including preliminary results from human factors research that suggests some of the possible reasons why, despite promises to the contrary, remote control has been shown to be no more safe than conventional switching operations.

We are currently finalizing a pilot project for close call reporting that will confer immunity on employees at a major terminal who contribute information regarding their

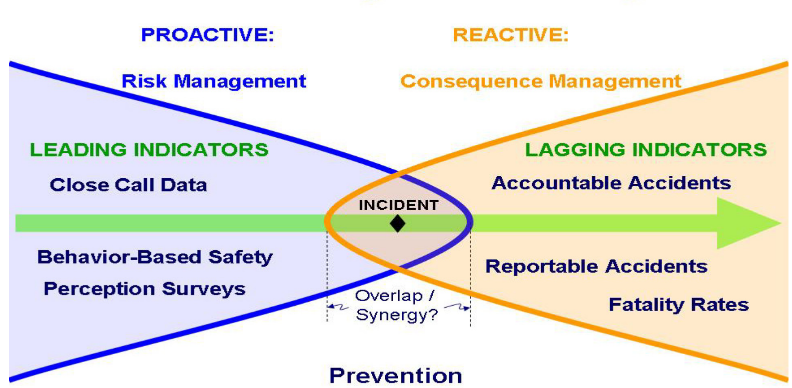


FIGURE 6 Transforming railroad safety.

own errors in the railroad operating environment with a major Class I railroad. A local team comprised of management, labor, and FRA will use this information to develop recommended solutions. If this effort—undertaken with the help of the Volpe Center and the Bureau of Transportation Statistics—is ultimately successful, we will follow U.S. aviation and other international industries that have used this approach as a powerful tool for reducing human factor incidents.

We tend to assume that more extensive use of technology will obviate the necessity to consider human factors. But experience teaches otherwise. From a human factors perspective, any change in how work is performed changes the tasks performed by the employees and consequently shifts the risks associated with that work. The introduction of new technology or changes in current technology can change how work is performed, and we should be cognizant of this. Various issues surround the introduction of new or altered technology, including the following:

- Usability: Is the technology fit to the human who has to use it, or will the human have to bend him- or herself to the technology?
- Utility: Is the design of the technology such that it serves a need in the job? Some technology seems like a good idea to the developer but is viewed as worthless or as a negative development by the people who have to use it (e.g., GovTrip).
- Workload: Automation technology is often designed with the goal of reducing workload for an operator. However, the things that can be automated often are the easiest things that the operator does, so that workload is not appreciably reduced and may even be increased if the technology is clumsy and requires frequent monitoring.
- Training: Workers must be trained to use the technology. The concept of technology operation is important. If workers are given no training in how the technology should be used, they will discover other ways to use it, and that can have undesired consequences.
- Situation awareness, fatigue, and alertness: The design of equipment can cause a range of problems, from boredom (because of lack of task involvement) to fatigue (caused by excessive mental workload). A heads-down display can result in a loss of situation awareness if the design of the display discourages obtaining information from the operating environment.
- Systems engineering: Where management and operating personnel are concerned, technology that reduces workload or increases working efficiency may translate to reduced operating costs and increased profits. By integrating human factors engineering in the systems design process, designs that meet human requirements are at the core of addressing operational safety issues. The development of hardware and software systems that address the proper integration of cost-saving technology to support people in the rail system systematically puts the focus on human-centered operational safety issues. In general, the systems design approach to technology should be human-centered, in which the human is considered as part of the system. The design should incorporate the human in the system from the beginning, rather than trying to adapt the technology to the human

after the fact. FRA is the leading voice advocating human-centered design, and we continue to build knowledge and tools that can assist designers and evaluators in making technology successful.

TRACK AND STRUCTURES

It can be argued that these are the best of times and the worst of times for railroad track and structures. On the one hand, the nation's rail infrastructure is now capable of providing record levels of service with what would be viewed historically as a high degree of safety. Significant progress has been made in building out the capacity needed for current traffic, and additional work continues. On the other hand, the cumulative effects of tonnages and higher axle loads have not been answered by adequate investment in the renewal of rail, special track work, or bridges. Recently, Congress responded to the pleas of small railroads for tax credits to make up their own investment deficit created in part by the increase in gross weight on rail to 286,000 lb for interchange cars. FRA continues to encounter bridge conditions on railroads of all sizes that require prompt attention—prompting us to question the present state of bridge inspection and rating programs, which must be fundamentally sound to support safety and to permit the development of capital programs.

Meanwhile, testing continues at Pueblo, Colorado, with an apparent serious thought of progressing to 315,000 lb. Before adopting a 286,000-lb interchange standard, the Association of American Railroads (AAR) conducted extensive research and analysis to determine whether the increase from 263,000 lb could be made safely and economically, assuming appropriate investment in equipment, track, and structures. Few would seriously contend that the introduction of 286,000-lb cars has, in fact, been managed in accordance with that plan. It is time for a moratorium on further increases in axle loads until a system-level analysis has been conducted and both government and the industry can understand what will be required to properly complete the transition. At the same time, project-level research must continue to help us manage the effects of the transition's residuals (e.g., unexpected axle failures, growing wheel problems). FRA must remain in a position to understand the basis and progress of all of the relevant work so that we can best apply public resources to areas of need.

Technology has greatly advanced our ability to inspect and find areas of safety concern. Technology has also produced numerous alternative and improved track components. However, numerous challenges still remain. Internal rail defects still constitute a significant factor in rail derailments, and current inspection techniques—which mainly use ultrasonic or electromagnetic probes—are adequate but far from perfect. As currently implemented, ultrasonic probes are often blinded by less significant surface defects that can deflect the ultrasound energy away from the potentially existing internal flaw. Defect sizing often is inaccurate, which complicates any remedial strategy for prioritizing defects that require immediate attention. FRA and the rail industry are working to promote the development of improved technologies for rail flaw inspection to address some of these concerns. We are curious whether any barriers to implementation have not been identified or fully considered.

Wide or weak track gage also remains a major source of rail accidents. FRA has pioneered technologies for the automated measurement of wide gage, as well as gage restraint [e.g., the gage restraint measurement system (GRMS)], and the industry has accepted and adopted the developed technology. GRMS technology has been proven successful at identifying problem spots and often is used in complement to visual inspection as an additional objective tool for the assessment of tie and fastener condition. Challenges remain in further reducing the cost of the GRMS technology for wider implementation. FRA has supported the development of lighter and more cost-effective GRMS through joint testing. FRA has also supported the development of a newer GRMS concept for increased reliability and increased efficiency through higher test speeds (the T-18). FRA also is updating current industry guidelines for GRMS testing to provide increased test consistency and objectivity for heavy and light systems.

Track geometry anomalies due to surface and subsurface degradation continue to play a factor in numerous derailments. FRA has been active in developing numerous technologies for automated track inspection. FRA's T-16 car is a moving platform for the development and deployment of many such technologies. These developments range from improved sensors for measuring track geometry and rail profile to advanced data management and display systems for the optimum real-time measurement and reporting of track geometry conditions. Rapid technological developments are now centered on data communication and display to remote sites for maximum effectiveness and on the use of Global Positioning System mapping for all detected conditions. Additional efforts are focused on developing cost-effective autonomous systems that can be fitted to working rail cars for true around-the-clock monitoring of track condition. These technologies promise to further revolutionize the way track is being monitored for its safety and performance.

As we look at existing developments and think about what the future holds, we must consider not only improved inspection techniques and devices but also the means to insert them into a context that can be used to manage the stresses on track structure. One example of this is the Track Quality Program, which offers a set of track quality indices that can be used to objectively assess the overall degradation rates and track conditions. It can work seamlessly side by side with the current approach used by our FRA track inspectors, who primarily rely on discrete results from exceptions to existing FRA track safety standards as recorded by our inspection and research cars. The prototype of a real-time Track Quality Index display program has already been installed on our T-16 research car and so far has yielded impressive results. This system allows for rapid and effective comparisons of relative track geometry quality. By using systems like this one, we can learn how to manage the track structure more efficiently and provide a tool for the railroads to better target maintenance and inspection programs.

While we are considering the track structure, we also must consider the subgrade.

One promising technology is track subsurface evaluation using ground penetrating radar (GPR). The roadbed is at least a contributing factor in accidents and incidents involving geometry, gage, and subgrade, which account for more than 50% of all track-related accidents. It is therefore critical to be able to efficiently and effectively evaluate the condition of the roadbed layers that are not subject to visual inspection. GPR can provide a continuous, nondestructive measurement technique for evaluating integrity. These measurements include substructure layer conditions and the potential to measure layer thickness, water content, and density of the substructure components (ballast, subballast, and subgrade).

The challenge is to incorporate better inspection techniques and technologies, improved components, and maintenance strategies in an integrated system that will allow for the real-time monitoring of track structure conditions. As we look at advances in health monitoring on the equipment side, we also should look to health monitoring on the trackside.

GEOSPATIAL DATA COMMUNICATIONS SPECTRUM ISSUES

Although grade crossing, human factor, and track accidents must all be reduced, we must pay attention to future technology advances in communications and determine the best fit for developments in geospatial data. We have seen technology transfer work well, but we must develop a means to make it organic to the R&D program.

One theme cutting across virtually all FRA's R&D elements is the use of sensors, computers, and digital communications to collect, process, and disseminate information to improve the safety, security, and operational effectiveness of railroads. Intelligent transportation systems (ITS) for highways and mass transit are based on these technologies, as are the new air traffic control and maritime vessel tracking systems. FRA and the railroad industry are developing intelligent railroad systems that will incorporate the new sensor, computer, and digital communications technologies into train control, braking systems, grade crossings, and defect detection as well as planning and scheduling systems. The new intelligent railroad systems are key to making railroad operations—freight, intercity passenger, and commuter—safer and more secure by reducing delays and costs, increasing effective capacity, improving customer satisfaction and energy utilization, reducing emissions, and becoming more economically viable.

The railroads operate 16,000 base stations, 90,000 mobile radios, 125,000 portable radios, and 5,000 trackside defect detectors in the 160.215- to 161.565-MHz VHF band. The Federal Communications Commission (FCC) requires that the railroads convert from 25-kHz to 12.5-kHz channels. Although this change will create more channels, it also presents significant challenges over the conversion period, the next 5 years. To facilitate this conversion, AAR has partitioned FCC to consolidate more than 6,000 licenses, covering 16,000 base stations, into a single ribbon license that runs along the mainline railroads. After the conversion to the narrowband channels is complete, the new channels will fill a significant pent-up demand for data and voice communications, especially in the area of PTC. In addition to the 160-MHz VHF band, the railroads use the

220- to 222-MHz band for remote control locomotives, the 452- and 457-MHz for end-of-train device communications with the locomotive, and six pairs of frequencies in the upper UHF band at 900 MHz for PTC. The demand for bandwidth will continue to grow. What can FRA do to facilitate data integration, communication security, and reliability?

PTC SYSTEMS

PTC systems are integrated command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency. PTC systems will improve railroad safety by significantly reducing the probability of collisions between trains, casualties to roadway workers and damage to their equipment, and overspeed accidents. The National Transportation Safety Board (NTSB) has named PTC as one of its most-wanted initiatives for national transportation safety. PTC systems are comprised of digital data link communications networks, continuous and accurate positioning systems (e.g., the Nationwide Differential Global Positioning System), onboard computers with digitized maps on locomotives and maintenance-of-way equipment, in-cab displays, throttle–brake interfaces on locomotives, wayside interface units at switches and wayside detectors, and control center computers and displays. PTC systems may also interface with tactical and strategic traffic planners, work order reporting systems, and locomotive health reporting systems. PTC systems issue movement authorities to train and maintenance-of-way crews; track the location of trains and maintenance-of-way vehicles; can automatically enforce movement authorities; and continually update operating data systems with information about the location of trains, locomotives, cars, and crews. The remote intervention capability of PTC will permit the control center to stop a train should the locomotive crew become incapacitated. In addition to providing a greater level of safety and security, PTC systems enable a railroad to run scheduled operations while improving running time, running time reliability, asset utilization, and track capacity. They will assist railroads in measuring and managing costs as well as improving energy efficiency.

However, PTC systems remain costly—too costly at present to envision widespread deployment, particularly where they are most needed, on passenger and hazardous materials routes. In the case of PTC, what can FRA do to reduce costs of this promising technology?

ROLLING STOCK

Rolling stock accidents are on the decline; however, we can still improve on inspection technologies, health monitoring, and derailment prevention and efficiency. FRA is currently working toward remote monitoring systems. In the current phase of the project, the monitoring system is being enhanced so that freight car mechanical components can be controlled remotely from a console in the locomotive or from a handheld device, such as a PDA. Controller area network technology is being used to develop a modular plug-and-play capability for integrating sensors and actuators with the monitoring system. The expanded system is referred to as the onboard monitoring and control system (OBMCS). Several advanced components developed by FRA under the Small Business Innovation Research Program are being integrated with OBMCS and will be remotely controlled from the locomotive. The advanced components include

- Auto-angle cocks,
- Tri-coupler,
- Auto-cut levers,
- Advanced hand brake actuators, and
- Cushion unit with remotely controlled lockout.

These remotely controlled systems can potentially improve the efficiency and safety of railroad operations.

Continuous onboard monitoring of mechanical components will enable railroads and fleet owners to detect defects early and proactively repair them before they cause breakdowns and accidents. Detection of a hunting truck would enable the locomotive engineer to slow or stop the train, thereby preventing a derailment. The use of one or more of the advanced components in freight operations would promote safety and improve efficiency. Operations that are presently performed manually (e.g., uncoupling cars, opening and closing angle cocks, and setting and releasing hand brakes) could be done via remote control from the locomotive, thus alleviating the need for railroad personnel to subject themselves to dangerous train operating conditions.

We can also improve on wayside monitoring. These stations can be used to identify potentially unsafe or defective equipment conditions and to quantify rate of wear and degradation so as to preclude unsafe equipment operation. These systems also may facilitate more effective and timely strategies for equipment maintenance and repair. If wayside detection systems are reliable and the data can be shared, then FRA may be able to review alternate strategies for regulatory compliance.

HAZARDOUS MATERIALS TRANSPORTATION

FRA, the tank car committee, and Volpe have undertaken a three-phase project toward the next step forward in tank car design. FRA started this research in 2002, after the derailment in Minot, North Dakota. The effort will lead to a better understanding of derailment forces on a tank car. As we gain understanding of derailment forces and work toward an improved tank car design, should we also consider alternate containment strategies? Can we create a self-sealing tank? Do technologies exist that we can apply efficiently and cost-effectively?

CHALLENGES TO THE SYMPOSIUM

What are the challenges for the next 5 years, and what should we reasonably hope to accomplish? How can FRA best integrate, through research, the shifts in demographics, the decreased capacity, and the increased stress of heavy axle loads to the components?

EFFICIENCY

EFFICIENCY

U.S. Railroad Efficiency

A Brief Economic Overview

Gerard J. McCullough, *University of Minnesota*

The focus of U.S. transportation policy in the 19th and 20th centuries was on extending the benefits of transportation to more locales and to more citizens. The focus of policy in the 21st century must also be on reducing the costs of transportation. Current transportation costs associated with safety, congestion, sprawl, and pollution are high. Future costs associated with the scarcity of petroleum could be cataclysmic.

The railroad network is a national asset that could be used to reduce the costs of transportation. This paper has two aims consistent with that possibility: to describe the efficiency improvements that the railroad industry itself has made in the past few decades, and to describe the role that the rail network could play in a more efficient overall national transportation system.

ECONOMIC EFFICIENCY IN TRANSPORTATION

After the 1974 and 1978 oil shocks, the U.S. Congress explicitly recognized the importance of an efficient transportation system. The Staggers Rail Act of 1980, for example, was designed to promote "a safe and efficient rail transportation system" (PL 96–448). Similarly, the Intermodal Surface Transportation Efficiency Act of 1991 had as its goal "a National Intermodal Transportation System that is economically efficient" (PL 102–240).

Emphasis on efficiency decreased in the 1990s. The Transportation Equity Act of 1998, for example, stressed fairness over efficiency (PL 105–178). With recent increases in oil prices, however, efficiency is back on the national agenda as indicated in the title of the Safe, Accountable, Flexible, Efficient Transportation Equity Act of 2005 (PL 109–59).

Efficiency has two formal economic aspects:

- Productive efficiency occurs when an economy cannot produce more of one good or service without producing less of another; it generally occurs when firms produce at minimum average total cost.
- Allocative efficiency occurs when the economy cannot raise one consumer's satisfaction without lowering another's; it occurs when price signals to consumers are based on marginal costs.

The focus of this conference is on techniques to improve rail network performance. We are concerned with the productive efficiency of railroad firms. We ask, what must be done to enable railroads to provide service at the minimum average cost that is technologically possible?

However, at the same time, everyone—including the manufacturers and distributors of most goods and services produced in our economy—consumes transportation services. The allocative efficiency of the transportation system within which railroads operate is also important. We must at least raise the question of whether the rail network is playing its proper role within our overall transportation system. Are we realizing the rail network's potential?[1]

PRODUCTIVE EFFICIENCY OF U.S. RAILROADS

The Staggers Rail Act gave railroad managers discretion to use pricing and service levels (often reached through contract negotiations with shippers) to affect the composition of rail output. Changes in output composition, along with the abandonment of lines and a significant degree of industry consolidation, have led to higher traffic densities, longer lengths of haul, and a significant shift in types of train operations.[2] Changes in the composition of rail output are illustrated in Figure 1.

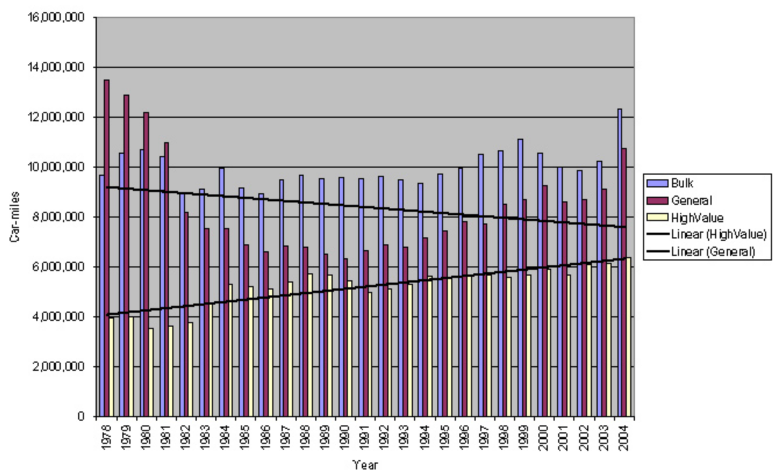


FIGURE 1 Railroad car miles by car type (*1*).

In 1978, the Class I industry—that is, freight rail with revenues exceeding $319.3 million annually—generated about 13.5 billion loaded and empty general car miles (where *general* refers to boxcar, gondola, reefer, and general purpose flat car miles); by 2004, the number had dropped to 10.8 billion. In the high-value market, on the other hand, intermodal and multilevel auto carrier car miles increased from 3.9 billion in 1978 to 6.4 billion in 2004. Meanwhile, loaded and empty bulk car miles (open hopper, closed hopper, and tank) increased from 9.7 billion to 12.3 billion.[3]

The operational changes have been dramatic. The annual *Analysis of Class I Railroads* from the Association of American Railroads (AAR) shows that between 1978 and 2004, revenue ton-miles increased from 4.5 million to 12.2 million per mile of road, average lengths of haul have

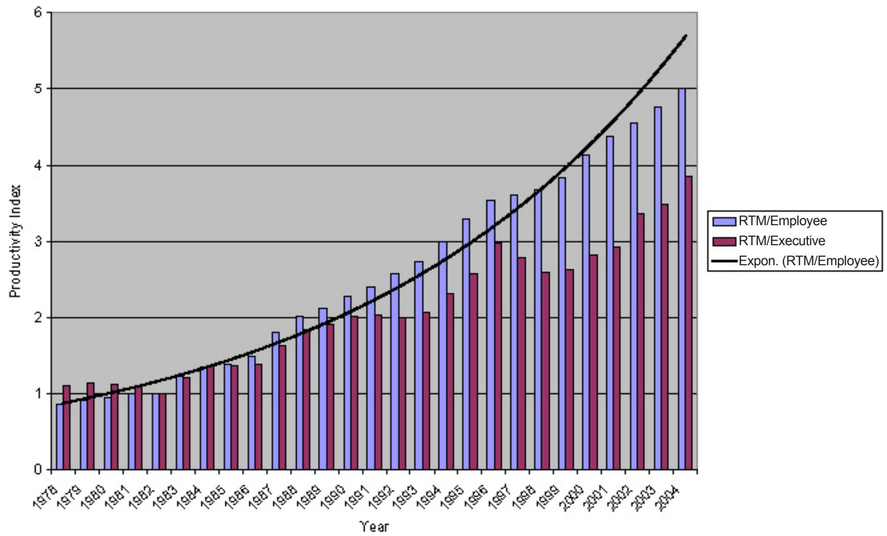


FIGURE 2 Railroad revenue ton-miles (RTM) per employee (*1*).

increased from 617 mi to 902 mi, and train miles completed in unit trains have expanded from 7% to 37% (*1*).

Operational changes have been accompanied by various technological improvements, including higher adhesion locomotives, reengineered rails and cars, better maintenance-of-way equipment, and automated inspection techniques. The overall effect has been a much higher level of productive efficiency in the rail industry. Labor output increased from 1.8 million to 10.5 million revenue ton-miles per employee between 1978 and 2004 (Figure 2).

Fuel productivity increased from 216.4 to 408.5 revenue ton-miles per gallon during the same period (Figure 3).

Equipment productivity increased as well: revenue ton-miles per locomotive

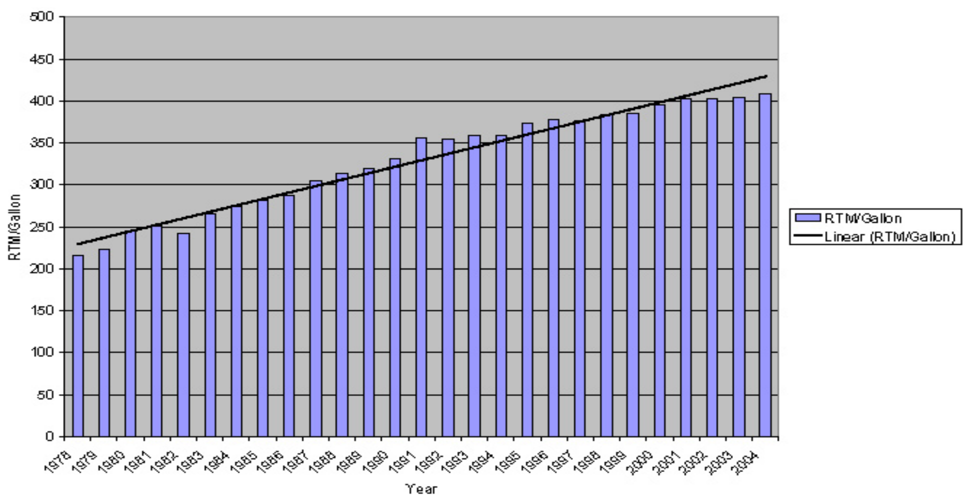


FIGURE 3 Railroad RTM per gallon of fuel (*1*).

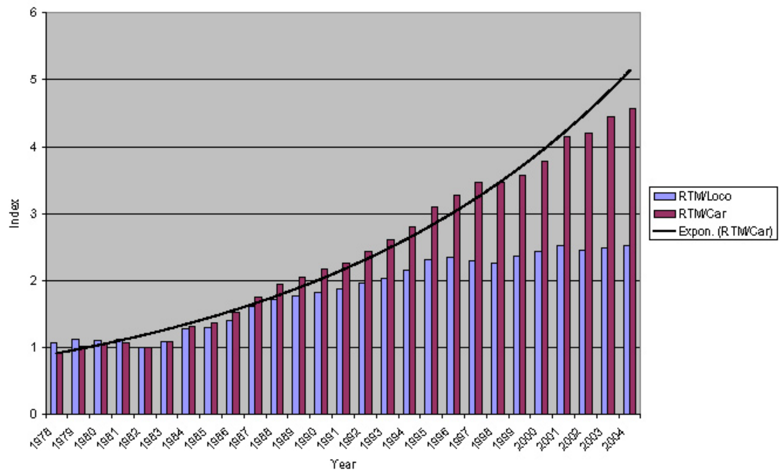


FIGURE 4 Railroad RTM per unit of equipment (*1*).
[All data are from editions of *Analysis of Class I Railroads* (*1*).]

increased by about 250%, and revenue ton-miles per freight car has increased by about 450% (Figure 4).[4]

The economic effect of these changes has been a significant reduction in railroad operating costs. They are illustrated by the bottom line in Figure 5—operating expenses per revenue ton-mile, which dropped from 2.46 cents (current) in 1978 to 2.11 cents (current) in 2004. (The top line in Figure 5, operating revenue per revenue ton-mile, is treated as a dimension of allocative efficiency.)

U.S. RAILROADS AND ALLOCATIVE EFFICIENCY

The role of transportation in fostering economic growth may have been exaggerated by highway builders and others who benefit directly from transportation spending. It is ana-

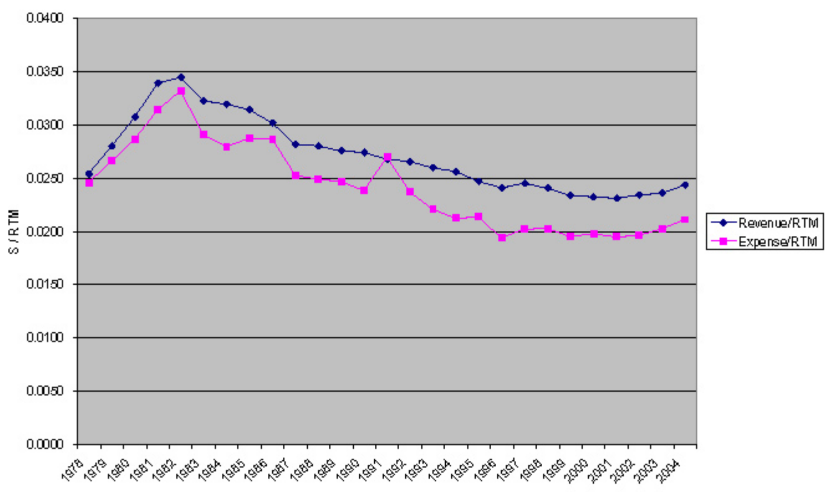


FIGURE 5 Railroad revenue and expenses per RTM.

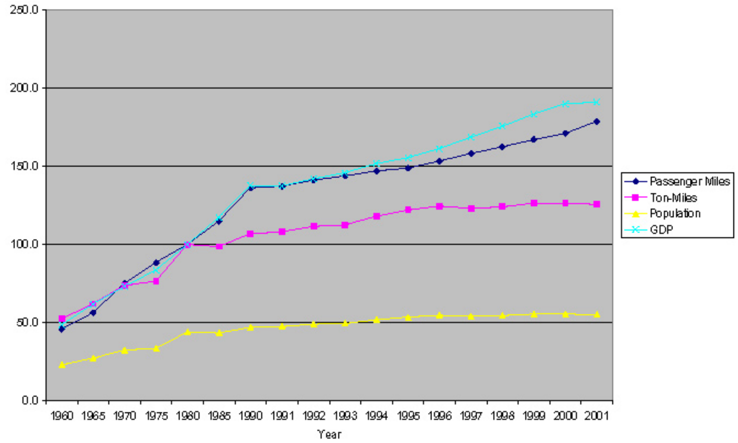


FIGURE 6 All transportation and economic activity (indexed to 1982 = 100).
(SOURCE: *National Transportation Statistics*,
www.bts.gov/publications/national_transportation_statistics.)

lytically difficult to disentangle the extent to which transportation investment generates economic activity or economic activity spurs transportation investment.

Nevertheless, transportation activity and economic activity are closely connected. Figure 6 illustrates how activity in national passenger and freight transportation markets [measured by vehicle miles traveled (VMT)] is correlated to real gross domestic product (GDP) and population. Clearly, transportation is an important constituent of economic activity.

Various independent studies have shown that railroads have a definite allocative efficiency advantage over other modes in providing some transportation services. When all costs are taken into consideration—internal costs absorbed by firms and external costs such as pollution and congestion—railroads often exhibit lower marginal costs than the other modes. An efficient economy would favor railroads in these cases. One reason this might not happen is that political authorities find it difficult to impose these external costs on truckers and shippers in the form of user fees for congestion, pollution, and safety.

TRB *Special Report 246* compares the full marginal cost of freight transportation by truck and rail in representative corridors (*2*). Table 1 compares the marginal cost of moving a truckload of grain some 215 mi from Walnut Grove to Winona, Minnesota. The costs of the rail mode are significantly lower overall when external effects are considered.[5]

One allocative concern is that rail industry consolidation has not only helped to increase traffic densities and lengths of haul, it also has increased rail market power. The Herfindahl–Hirschman index (HHI) is the standard measure that the U.S. Department of Justice uses to measure market concentration.[6] As the number of Class I railroads dropped from 36 firms in 1978 to 7 in 2004,[7] the HHI (Figure 7) increased from 589 to 2,263, well above the 1,000 HHI trigger point at which the Justice Department begins to carefully scrutinize mergers.

TABLE 1 Freight Marginal Costs (dollars)

Category	Truck	Rail
Congestion	6.25	0.00
Accident	26.11	9.19
Pollution	6.75	1.43
Energy security	3.63	0.39
Noise	0.00	0.78
Public infrastructure	61.02	0.00
Carrier cost	427.94	113.00
Total	531.70	124.87

SOURCE: *Special Report 246: Paying Our Way: Estimating Marginal Social Costs of Freight Transportation,* TRB, National Research Council, Washington, D.C., 1996, p. 90.

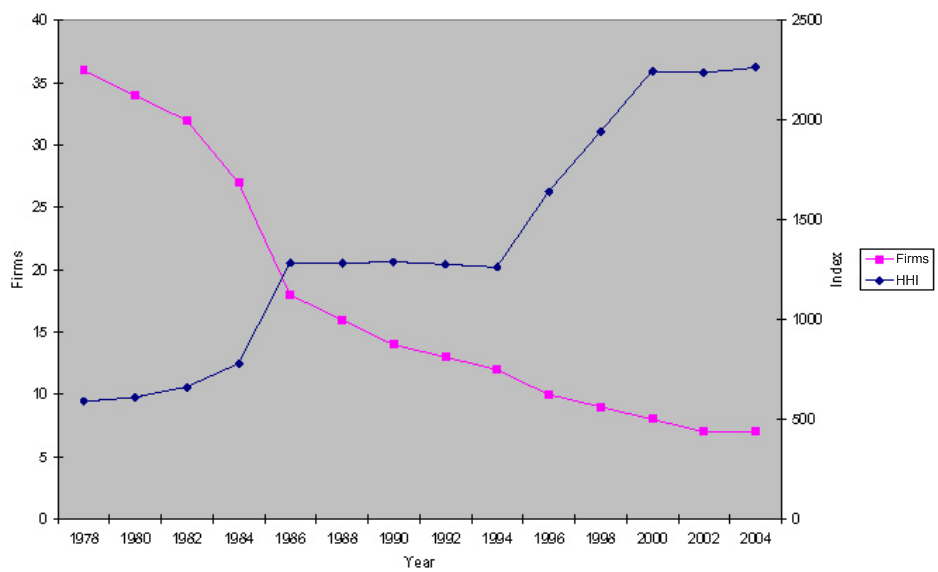


FIGURE 7 Class I railroad industry Herfindahl–Hirschman index, calculated from AAR *Analysis* (*1*) on the basis of carloads originated.

TABLE 2 Freight Market Shares

Mode	1993	1997	2002	Change (%)
Truck	869.5	1,023.5	1,311.1	50.8
Rail	942.6	1,022.5	1,199.4	27.2
Water	272.0	261.7	323.1	18.8
Air	4.0	6.2	5.6	38.7

NOTE: Ton-mile × 10^9.
SOURCE: Based on data from *National Transportation Statistics*, www.bts.gov/publications/national_transportation_statistics.

Until recently, however, railroads to some extent shared with shippers the cost reductions brought about by efficiency improvements.[8] Figure 5 shows that despite increases in market power, operating revenue per ton-mile declined from 2.54 cents (current) per revenue ton-mile in 1978 to 2.44 cents (current) per revenue ton-mile in 2004.[9] The pricing discipline enabled railroads to maintain a significant share of the freight market; Table 2 data indicate that railroads now carry about 40% of U.S. freight ton-miles inter- and intracity.

Railroads may also have an allocative efficiency advantage in some passenger markets as well, but it is influenced by ridership levels as well as vehicle performance. Table 3 compares the fuel intensity of competing intercity passenger modes.

Both Amtrak intercity service and rail transit have energy efficiency advantages over intercity auto, transit buses, and air but not intercity buses. The report does not evaluate commuter rail services, where railroads probably perform even better in terms of energy efficiency.

CONCLUSIONS

We still lack the data necessary to define the proper role of rail passenger service in the United States, but freight railroads clearly have an allocative efficiency advantage in various markets. Although freight railroads have made significant gains in productive efficiency, rail freight is still one of the slowest growing modes of transportation in the United States. Figure 8 shows that since 1980, rail freight VMT has actually grown less rapidly than highway freight VMT or even rail passenger VMT. Figure 9 illustrates one interesting outcome: Since 1998, the freight system has become more labor efficient but not more energy efficient. This finding should lead to a serious consideration of whether our national transportation policies are moving away from allocative efficiency.

TABLE 3 Energy Efficiency: Passenger Modes, 1998

Mode	Btu/passenger mile
Automobile	3,671
Transit bus	4,238
Intercity bus	713
Air carriers	3,999
Intercity rail	2,460
Rail transit	3,216

SOURCE: *2000 Transportation Energy Data Book,* Table 2.12, http://cta.ornl.gov/data/tedb25/Spreadsheets/Table2_12.xls.

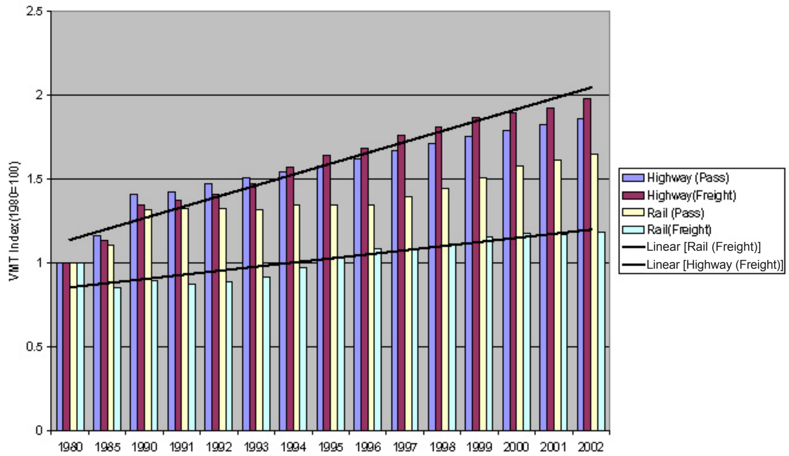


FIGURE 8 Surface transportation VMT growth by mode (indexed to 1980 = 1).
(SOURCE: Based on data from *National Transportation Statistics*, www.bts.gov/publications/national_transportation_statistics.)

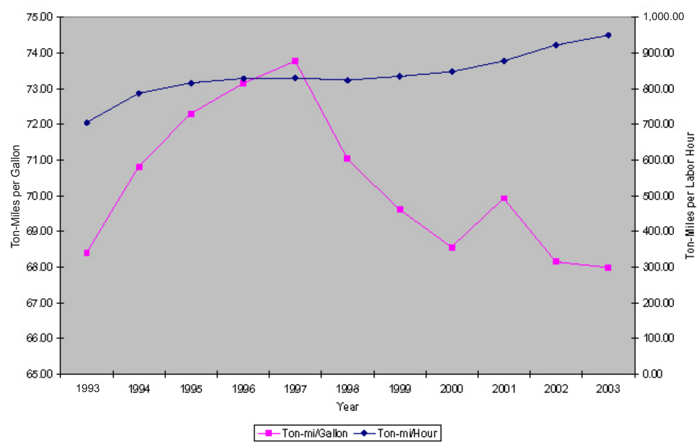


FIGURE 9 Surface freight system efficiency.
(SOURCE: Based on data from *National Transportation Statistics*, www.bts.gov/publications/national_transportation_statistics.)

NOTES

1. An increase in the allocative efficiency of the transportation system probably will increase the productive efficiency of railroads as well. Econometric studies have shown that railroads exhibit increasing returns to density. This means that as the railroad share of the freight transportation market increases (allocative efficiency), railroads themselves will be able to produce at lower marginal cost (productive efficiency). See, for example, Ivaldi, M., and G. McCullough, Density and Integration Effects on Class I U.S. Freight Railroads, *Journal of Regulatory Economics,* Vol. 19, No. 2, 2001, pp. 161–182.
2. Abandonments and consolidations also were facilitated by the Staggers Rail Act.

3. The capacity of these bulk cars increased significantly as well. Coal is increasingly carried in rotary coupler–equipped cars classified as gondolas rather than hoppers, so some adjustment may be needed to correct for this factor.
4. What we report here are partial productivity measures in which outputs (e.g., revenue ton-miles) are divided by a specific input (e.g., labor hours). Other total factor productivity measures are available that account for not only the relative increases of outputs and inputs but also the residual effect of technological progress (i.e., more efficient combinations of factors such as capital and labor). Most recent econometric studies of rail costs show total factor productivity gains in the rail industry of about 3% to 4% annually. See, for example, Ivaldi, M., and G. McCullough, *Subadditivity Tests for Network Separation Using a Generalized McFadden Cost Function,* CEPR Discussion Paper 4392, Center for Economic Policy Research, London, U.K., May 2004.
5. One calculation missing in the TRB report is the total logistics cost that the shipper faces when using rail versus truck. Truck transit times are usually better, and this lowers time-related total logistics costs.
6. If S_i is the percentage of output that a firm provides in a given market, then HHI is given by the formula

$$\mathrm{HHI} = \sum_i S_i$$

7. In 1980, the ICC changed the definition of Class I and ended reporting requirements for non-Class I railroads. The revenue threshold definition for Class I was raised to $250 million at the end of 1992 and since has been adjusted annually for inflation.
8. The dynamics of railroad pricing behavior are beyond the scope of this brief paper. Intermodal, intramodal, product and geographic competition, the bargaining power of large shippers, and potential intervention by the Surface Transportation Board are all possible elements that affect prices.
9. The operating revenue per ton-mile measure is only a proxy for average prices. It does not measure the degree to which railroads charge different prices to different customers.

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1. *Analysis of Class I Railroads* (annual publication). Association of American Railroads, Washington, D.C., 1978–2004.
2. *Special Report 246: Paying Our Way: Estimating Marginal Social Costs of Freight Transportation.* TRB, National Research Council, Washington, D.C., 1996.

EFFICIENCY

Rail Transportation in the 21st Century

Summary of Remarks

Matt Rose, *Burlington Northern Santa Fe Railway*

Railroads are the most efficient form of surface transportation, but how do we get more out of our rail network to continue to handle record volumes?

Efficiency and capacity are closely intertwined, and they have significant implications for the rail industry's long-term growth as part of the global supply chain. Technology is an important part of the solution, as are increased capital investment and a thoughtful regulatory environment.

THE STAGGERS ACT AND RAIL CAPACITY

Between 1980 and 2000, the rail industry had excess capacity. The Staggers Act led to dramatic increases in railroad productivity, which enabled the industry to handle sharply higher volumes while reducing prices and working off excess capacity. As an industry, our revenue ton-miles increased more than 80% from 1980 to 2004 while miles of track owned, number of freight cars in service, and employment figures all decreased dramatically in response to efficiency initiatives (Figures 1 and 2).

However, over the past 5 years, gross ton-miles (GTMs) have loaded up the railroads, putting stress on our infrastructure. Today, railroads are poised to shoulder more of the transportation burden if we can consistently realize the returns that justify new investment. We must continue to embrace the policies introduced with the Staggers Act and give railroads the freedom to operate in the marketplace without artificial constraints.

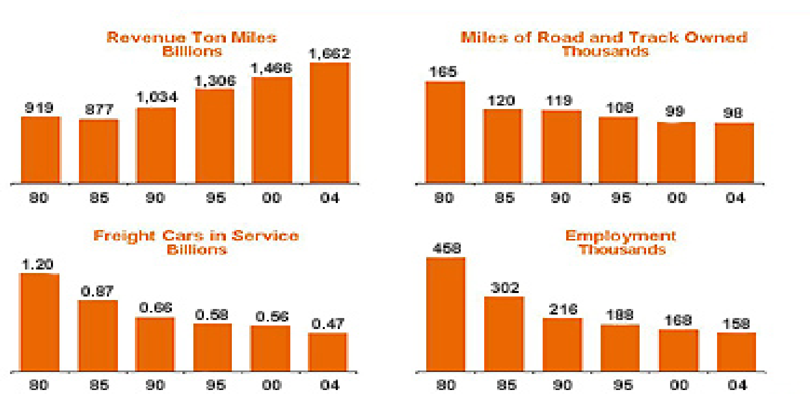


FIGURE 1 Class I railroads.

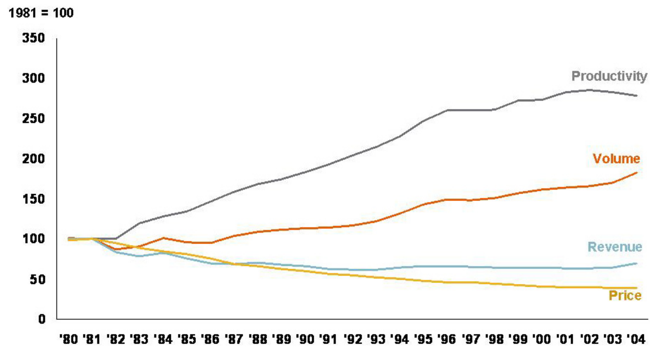


FIGURE 2 Class I railroads' performance, 1980 to 2004.
(SOURCE: Association of American Railroads.)

STRATEGICALLY CREATING MORE CAPACITY

Rail ton-miles traditionally have tracked industrial production, but in the past few years, the U.S. economy has shifted its focus from production to consumption. In 2003, for the first time since 1996, rail ton-miles surpassed industrial production, and that trend continues.

Burlington Northern Santa Fe (BNSF) Railway has grown from a little more than 7 million carloads in 1995 to more than 10 million carloads in 2005, with most of that growth in intermodal, especially international intermodal business (Figure 3).

Demand currently outstrips capacity. How do we become more efficient and create more capacity? What we're doing at BNSF is illustrated in Figure 4, and highlights of these efforts are described below.

Velocity Improvement

Increasing the velocity of our locomotives, railcars, and other assets will help us increase capacity by improving the use of existing assets. This important focus underlies all of our major corporate initiatives.

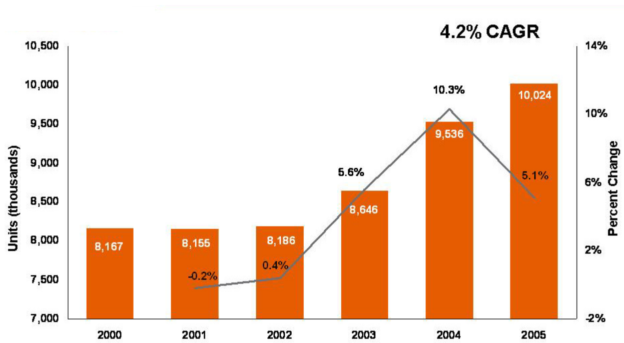


FIGURE 3 BNSF volume growth, 2000 to 2005.
(CAGR = compound annual growth rate.)

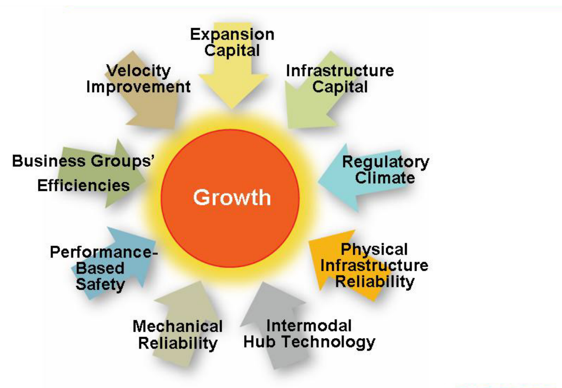


FIGURE 4 How BNSF continues to improve efficiency.

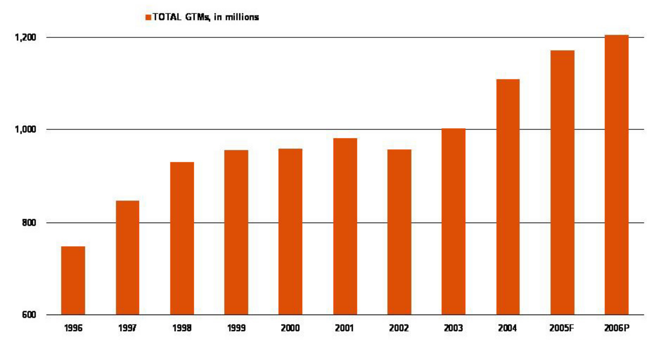


FIGURE 5 Increased demands on physical infrastructure, as measured in gross ton-miles (GTMs).

FIGURE 6 Increased investment in physical infrastructure: Maintenance capital is being invested to improve reliability and velocity.

Physical Infrastructure Reliability

Maintaining a strong railroad (i.e., rail, ties, ballast, and roadbed) is the foundation for efficiency and growth. Capital investment renews our assets and extends the life of those assets (Figures 5 and 6). We also emphasize the measurement of track quality and the identification of potential track geometry defects to increase velocity and reliability (Figures 7 and 8).

Intermodal Hub Technology

More than half of our volume now is intermodal. Technology helps us prepare for efficient intermodal growth, including the transmission of real-time information as the driver arrives at an intermodal gate through train departure; efficient overhead crane technology

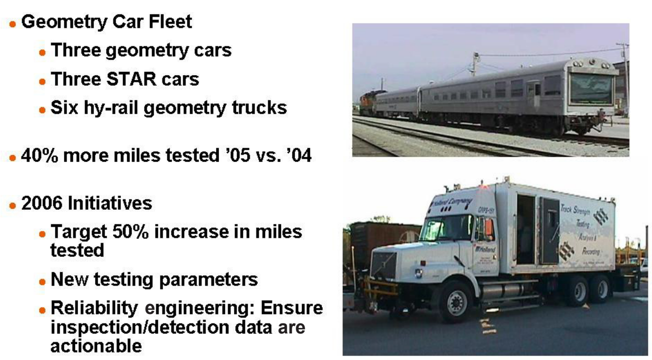


FIGURE 7 Physical infrastructure detection technology.
(STAR = Suburban Transit Access Route)

FIGURE 8 Next-generation rail detection.
(TTCI = Transportation Technology Center, Inc.)

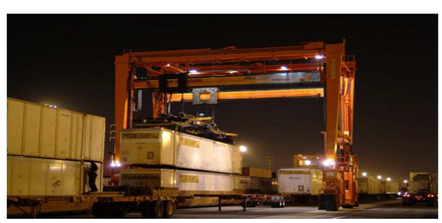
- **Oasis RF hub management and automated checkpoints**
  - **Real-time event reporting using computerized hub equipment**
  - **Immediate work instructions improve efficiency by 30%**
  - **Handheld computers and driver input kiosks reduce transaction times by 50% at checkpoint**

(*a*)

- **Improved cranes**
  - **Damage-Free Lift reduces damage by 25%**
  - **GPS steering improves crane efficiency by 13%**
  - **Elevated cabs on cranes improve efficiency by 15%**
- **Container stacking cranes increase capacity up to 500%**
- **GPS automatic container stack inventory improves efficiency by 15%**

(*b*)

- **Oasis RF hub management and checkpoint systems**
- **Automated checkpoints**
- **Improved cranes and lift technology**



(*c*)

FIGURE 9 Intermodal hub technology: (*a*) transmission of real-time information as the driver arrives at an intermodal gate through train departure; (*b*) efficient overhead crane technology and GPS-based steering to reduce damage; (*c*) investments in state-of-the-art facilities close to large distribution zones or ports of entry.

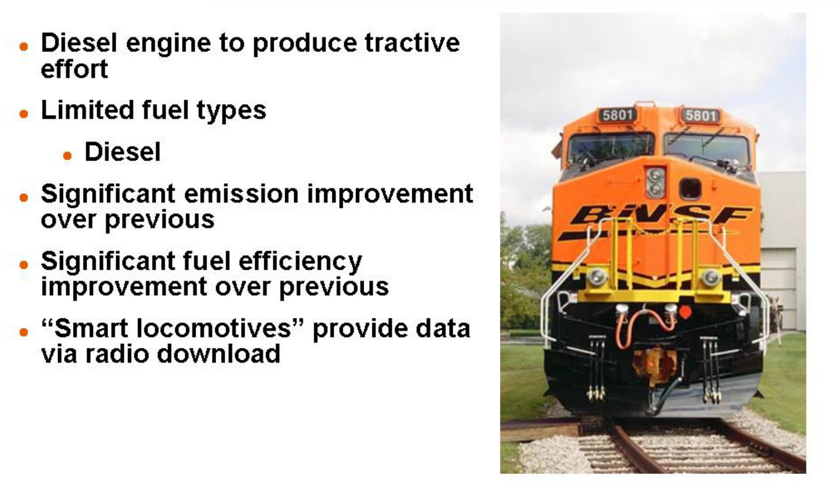


FIGURE 10 Current locomotive technology.

and Global Positioning System (GPS)-based steering to reduce damage; and investments in state-of-the-art facilities close to large distribution zones or ports of entry, as in the Southern California International Gateway (Figure 9).

Mechanical Reliability

Our locomotive productivity has improved more than 30% since 1980. Two new 4,400-hp DC locomotives replace three older 3,000-hp locomotives, and three AC locomotives do the work of five 1980 units. We've also improved fuel efficiency and reduced emissions (Figure 10). Alternate fuel technology—hydrogen fuel cells, biodiesel, liquefied natural gas—could further reduce emissions (Figure 11). Reducing the stress state of the railroad through regenerative braking and "smart" locomotives for train crews could further improve productivity.

Our renewed focus on car technology will improve productivity, extend asset life, enhance safety, and reduce the stress state of our infrastructure (Figure 12).

FIGURE 11 Future locomotive opportunities.

- Improved productivity
  - Net/tare ratio
- Increased asset life
  - Reduced component failures
- Designs enhanced for safety
- Reduced impact on infrastructure

FIGURE 12 Current freight car technology.

It includes technologies such as hot box detectors, wheel impact load detectors, and acoustic bearing detectors. We can further improve the productivity of our freight cars and network through better truck performance and electronic or hybrid brakes (Figure 13).

Business Group Efficiencies

For each of our four business groups, efficiency helps us grow and leverage capacity. With increased coal demand, we've added more than 150 coal sets on our network in the past decade—to 426 sets in the first 4 months of 2006. We are also loading about 2,500 more tons per coal train than in 1995 and more tons in every car.

International intermodal business accounts for 64% of our volume growth since 1995, and domestic intermodal accounts for 16%. Improving the efficiency of our intermodal network has enabled this growth. Equipment has evolved from 40-ft trailers in 1980 to today's 10-pack double stack with 53-ft containers. Investments in double- and triple-track work have increased capacity along our transcontinental main line between Chicago, Illinois, and Los Angeles, California. By the end of 2006, fewer than 100 mi of this 2,200-mi route will remain to be double tracked. We've also invested in new and expanded facilities, especially in California and Chicago, to enhance capacity and handle our dramatic intermodal growth.

- Components
  - Increased productivity, reduced weight
  - Increased reliability
- Component design to facilitate vision system inspection
- Improved truck performance
- Hybrid brake system

FIGURE 13 Future freight car opportunities.

What is AIM?

- **An objective supporting BNSF's "Reshaping the Carload Network" initiative to improve the efficiency and fluidity of the BNSF carload network.**
- **Benefits will include:**
  - **Service—improved velocity**
  - **Franchise—balance resources**
  - **Return—achieve sustainable returns to help justify reinvestment**

FIGURE 14 Carload process redesign: AIM.

Our agricultural business has grown by 100,000 units over the past 10 years to more than 915,000 units; our shuttle train network introduced in 1996 has helped us accommodate this growth. A car on a grain shuttle train handles, on average, three times more volume than a single grain car because of efficiencies and velocity improvements that come with shuttle trains.

In industrial products, we serve about 6,000 customers, using many car types and hundreds of origin–destination pairs. AIM (Assess, Improve, Maximize) is an important efficiency and capacity initiative. In this multiyear effort, we're surveying key carload customers and products, with the goal of redefining our baseline offerings, streamlining our network, and moving toward a more scheduled network (Figure 14).

Performance-Based Safety

Another big contributor to rail efficiency and network fluidity is safe production. BNSF has steadily reduced the number and severity of injuries each year. Technology plays a big role in these improvements. We have been working for several years on the Electronic Train Management System (ETMS), a positive train control (PTC) system that provides a safety net for train operations while retaining the existing operations and rules as a primary means of train control (Figure 15).

- **EMTS is a positive train control system.**
- **NTSB defines PTC as the means to "prevent train collisions and overspeed accidents by requiring automatic control systems to override mistakes by human operators."**
- **FRA reported accidents for 2004:**
  - **178 head-on, rear-end, and side collisions.**
  - **160 or 90% attributed to human factor causes.**
- **EMTS provides positive train control by mitigating the potential of catastrophic consequences caused by human error.**

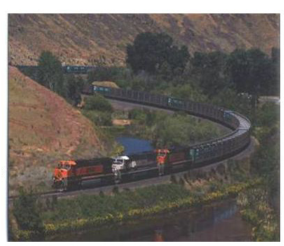


FIGURE 15 Why ETMS?
(NTSB = National Transportation Safety Board.)

- **EMTS is a <u>safety-critical overlay</u> system that works in conjunction with existing methods of train operations.**
- **Works in conjunction by providing a "safety net" for train operations while retaining the existing operations and rules as a primary means of train control.**
- **ETMS <u>enforces compliance</u> with existing methods of operation and rules.**
- **Compliance enforcement includes train movement authorities, speed restrictions, and work zones.**
- **Any noncompliance and ETMS stops the train before an incident.**

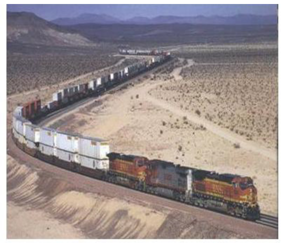


FIGURE 16 What is ETMS?

ETMS enforces train movement authorities, speed restrictions, and work zones; following any noncompliance, ETMS stops the train before an incident (Figure 16). ETMS also will provide some capacity benefits by delivering movement authorities more efficiently and eliminating incidents and service interruptions due to movement authority and speed limit violations, misaligned switches, and broken rails (Figure 17).

INVESTING TO INCREASE CAPACITY

In the 10 years since our merger, we've invested about $22 billion to maintain our physical plant and increase capacity through expanded track, yards, and terminals; new locomotives; and technology. We expect capital commitments of about $2.5 billion in 2006. With the volumes we are seeing, increases in maintenance capital are also required to improve capacity. Estimates for 2006 include an additional $70 million for more rail, ties, and ballast.

Now

- **Timely delivery of movement authorities**
- **Reduces service interruptions**
- **Reduces or eliminates signal requirements on new track construction**
- **Allows operation of additional trains in nonsignaled territory through automated roll-up of track authorities**

Future

- **ETMS components enable movement planning and train pacing**
- **Elimination of signal system to reduce spacing**

FIGURE 17 Capacity benefits of ETMS.

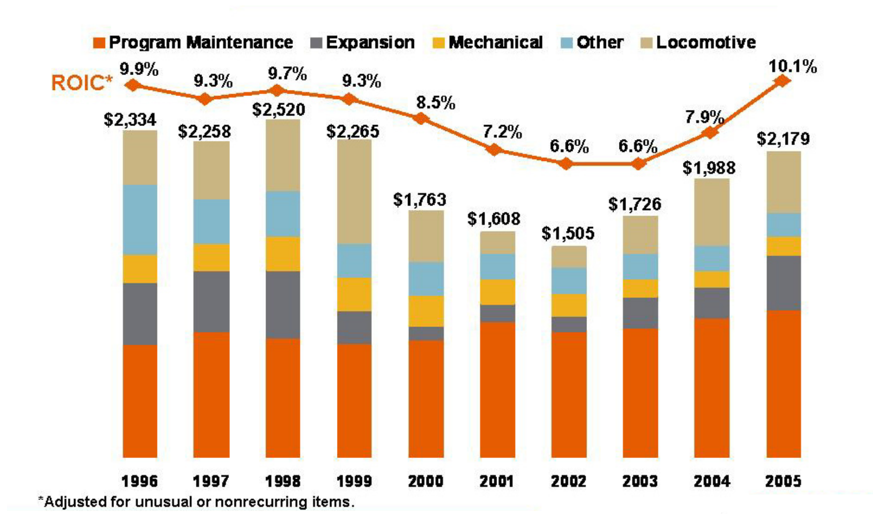


FIGURE 18 Capital commitments with return on invested capital (ROIC) in millions of dollars.

Shippers want more capacity, we want more capacity, and this nation's economy depends on us having more capacity. However, most capital comes directly from the rail industry. In 2005, railroads invested $9.25 billion in their networks, while federal funding only contributed $170 million. Of that figure, $155 million was for Section 130, which was grade crossing funding that did not add any capacity.

Our rate of return on invested capital is directly related to our ability to reinvest in our existing business to accommodate growth (Figure 18). We must sustain our returns to reinvest in our network. So the question is this: how do we get additional investment in rail capacity?

- Direct government investment: Non-market-driven investments by government will cause disinvestment by rail industry.
- No change to current model: As railroads improve their returns, more expansion capital will be put in the networks. The current regulatory system must be maintained as part of this; a market-based model is essential to achieving desired outcome.
- Supplement current model with stimulus: The stimulus will encourage investments to be made sooner in their cycle but will not be enough to encourage a bad investment.

Increasing the expansion capital in the industry from around $2 billion to $4 billion would have a tremendous impact on expansion.

RESEARCH TO ENHANCE RAIL NETWORK PERFORMANCE

LOOKING TO THE FUTURE

Rail volumes are growing as transpacific trade increases and more trucking firms turn to rail. The current discussion to increase truck size and weight seems counterproductive, especially in view of highway safety concerns, congestion, and emissions.

Rail increasingly appears to offer the answer to the nation's freight transportation needs, and we have tremendous potential to expand the capacity of the nation's railroad network—if conditions are right. We are investing significantly in our network to improve the efficiency of our technology, people, and processes. Up to this point, these gains have been almost exclusively dependent on our own capital investment in addition to whatever velocity and asset-use gains we can make by leveraging existing and new capacity.

However, our ability to provide additional capacity ultimately depends on thoughtful public policy and a regulatory and environmental framework conducive to growth. Senator Trent Lott's 25% investment tax credit proposal is one example of public policy that can encourage continued investments in rail capacity while providing an environmental review that allows good projects to come on line in time to meet capacity demands.

Much more is needed. Our ability to provide an efficient rail network to handle the nation's commerce hangs in the balance.

EFFICIENCY

Efficiency Issues

A Passenger Rail Perspective— Summary of Remarks

Conrad Ruppert, Jr., *Amtrak*

Because of a last-minute change in the Amtrak Board of Directors' meeting schedule, David Hughes will not be able to attend this session, and he asked me to step in for him. He extends his apologies, as he appreciates the importance of this workshop and had wanted to be here. I will not be directly reading his prepared remarks. Instead, I will present some of the thoughts he wanted to convey on the subject of efficiency as it relates to research needs to enhance rail network performance, as well as some of my own ideas.

I do not necessarily have the same perspective on things as Mr. Hughes might have, given the differences in our railway experience. I have had the opportunity to view things from the "upper floors," looking at the railway passenger industry with a big-picture perspective, yet I have also spent time taking the elevator to the ground floor and seeing things from track level. I hope that I can blend these perspectives and support the goals of this workshop. My main objective is to stimulate thought on the subject of efficiency and perhaps contribute to the discussions in the breakout sessions.

EFFICIENCY DEFINED

Let's take a look at a definition of *efficiency*: "the production of the desired effects or results with the minimum waste of time, effort, or skill." This is a particularly useful definition of efficiency because it first speaks to the "production of desired results or benefits." In other words, we must first have the end in mind if we expect to measure and improve efficiency.

The definition next speaks to minimizing "waste of time, effort, or skill." Waste can relate to efficiency in a purely technical sense because it relates to "hard" technology and can also relate to the time, effort, and skill of our workforce.

As we heard from some of the preceding speakers, we use key corporate or strategic metrics to measure efficiency. From a passenger rail perspective, we share many of these metrics with freight rail, yet with some differences. Strategic metrics are important because they give a measure of the health of the corporation and industry and provide a means to measure improvement.

We also need metrics at a tactical level that support the strategic. They provide the necessary measures to people in the field who ultimately will be the driving force that allows us to improve and work more efficiently.

TOP 10 EFFICIENCY ISSUES

What follows is a top-10 list of efficiency issues as they relate to enhancing rail network performance. It is not a definitive list; they simply are some key issues that I believe need to be addressed as we define research needs.

1. Create a Safe Environment for People.

This item applies both to the passengers we carry and to our employees.

We take our responsibility to provide a safe environment for our passengers seriously. As our rule book states, safety is of first importance in the discharge of duty. There is no compromise when it comes to passenger safety.

For our employees, we work in what is by nature a hazardous environment. One example is at "A" Interlocking leading into Penn Station, New York. More than 500,000 people pass through this station each day. With the volume and frequency of revenue train moves in addition to switching moves, it is an extremely hazardous place to work. Yet the presence of hazards does not necessarily imply an unsafe environment. With the permission of the Norfolk Southern (NS) Railroad, Amtrak's engineering department essentially adopted the NS safety program (for the simple fact that it works). The first two fundamentals of safety are that (a) all injuries can be prevented and (b) all hazards can be safeguarded against. Safeguarding against hazards, particularly through roadway worker protection (RWP) measures, can often be costly. Hence, it is important that part of our research efforts focus on methods to improve RWP safeguards with an eye toward efficiency.

There also has been a misperception or myth in the industry that when focusing on safety, we somehow compromise efficiency. Nothing could be farther from the truth. In fact, a safe environment by nature is an efficient environment. For example, consider the efficiency of a worker idled by an on-the-job injury, whose productivity or efficiency is zero. Furthermore, if the position that the worker vacates is a critical one, then it is more than likely being filled on overtime, because we have a limited pool of labor resources on which to draw. Lack of safety directly affects our efficiency.

2. Manage Behaviors Affecting Operations.

Operations cover the full spectrum, from the engineer in the cab to the dispatcher in Centralized Electric and Traffic Control to the maintenance personnel repairing our fixed infrastructure and rolling stock. It also should focus on both good and bad behaviors, encouraging those behaviors that progress the efficient use of our capacity and discouraging those behaviors that impede it.

One example is good training that provides a lever to truly change behaviors. It starts with clear instruction but also must include feedback that measures the effectiveness of instruction. We frequently use what I call "catch and release" training. Like the fisherman who catches a fish and immediately releases it, we "catch" our employees, bring them into the classroom, and—when the training is complete—release them "back into the wild" with inadequate feedback to evaluate how well they learned what was taught. Often, the first feedback we get is when a mistake is made, at which point it becomes apparent that our training efforts were not effective. With this in mind, research efforts might include the use of technology for new methods to deliver training and periodically obtain feedback.

Managing behavior to get the most out of our assets could be an alternative to capital investment. It would be worthwhile to research methods to do just that (e.g., alternative means of delivering training and providing remote feedback).

3. Provide Performance Metrics.

Clearly defined performance metrics also can drive improvements in the efficient use of our limited capacity. Providing overarching metrics that can be broken down to levels of responsibility in the field is key. For example, at Amtrak, delay minutes are measured, linked to specific failure events in the infrastructure, and reported to the field managers. Feedback is received via a weekly review of failures and associated delay minutes. By implementing this simple task, both failures and delay minutes related to infrastructure failures have been considerably reduced. In turn, results have been observed in the overarching metric of on-time performance.

The participation of frontline leaders is essential in this process of performance metric provision and review. This front line is the best place to effect positive change in all aspects of operations. The challenge, which research efforts could help, is to clearly define the appropriate metrics with the systematic means to communicate performance results.

4. Effectively Deploy "Hard" Technology.

We do this to improve efficiency, including the physical infrastructure, the tools and equipment that we use to maintain it, and the technologies available to inspect and test performance. A challenge we face as engineers (i.e., people who tend to become enamored with tools and technologies) is to lose sight of the objective (i.e., improving operating efficiencies) by focusing on the wonders of the technologies themselves. Although research in technology improvement is important and should continue to be pursued, it should be understood that they often yield only incremental improvements in performance.

5. Follow a Systems Approach with a Network Perspective.

To quote the poet John Donne, "No man is an island, entire of itself … ." We must take a systems approach to everything that we do. To focus exclusively on the track, its problems, and performance while ignoring the vehicle that operates over it will only lead to

RESEARCH TO ENHANCE RAIL NETWORK PERFORMANCE

failures. The key is to provide the tools and information needed to manage the system interface. In the case of track, this is the dynamics of wheel–rail contact and vehicle–track interactions. Many such system interfaces exist throughout the railway network. Continued research to better understand and manage these interfaces is essential for operating and maintenance efficiencies.

The systems collectively function as a network and must be viewed as such. Network capacity and operating practices are inextricably linked. Better software tools to design and model the former and to aid in dispatching decision in the latter are essential to target potential capacity improvement projects and to improve network efficiencies.

The network also should be viewed from the passenger's perspective. Recalling the definition of *efficiency*, we should first note the "desired results" of the passenger—namely, to safely traverse the network from origin to destination. Of equal importance to the passenger is to minimize the "time, effort, and skill" to reach his or her destination. As our passenger rail network exists today (including high-speed rail, intercity, commuter, and transit), the saying "You *can't* get there from here" is often true. Phil Pagano of Metra remarked on the changing demographics in Chicago, where the flow of commuters is changing. The pattern is no longer inbound to center city in the morning and outbound to suburbia in the evening. Outbound-morning/inbound-afternoon traffic flows are increasing, as are intra-suburbia commutes. The need to better understand and model the effects of these changing demographics on network design and operation is important. As ridership continues to increase, we need to be able to say, "You *can* get there from here."

6. Provide a Clear Path from Data to Decisions.

Our problem is not the collection of raw data; we swim in it. It is the conversion of raw data to pertinent information with which we can make informed decisions. Significant progress has been made in this area over the past two decades. Yet as information technology continues to improve and the cost of wireless communications continues to decrease, we now have the ability to provide this information to frontline leaders. Furthermore, we now have the ability to direct and monitor our dispersed workforce through the integration of work order–based work management systems with low-cost Global Positioning System (GPS) tracking technologies.

7. Learn from Both Failure and Success.

Our tendency is to focus on failure—what we did wrong. Although much is to be gained through the root-cause analyses of failures, we also can learn from what we did right. Doing the right thing well is another definition of efficiency. Research to better understand the mechanisms of failure and success can only help us do the right thing well.

8. Prudently Use Our Limited Resources.

As we learned in yesterday's session, network capacity is a limited resource. Yet of even more importance, our people are the most valuable resource that we have. We are rapidly approaching the limits of this essential resource as our workforce ages and nears retirement.

Changing demographics and cultural values provide challenges to attracting and retaining a qualified workforce. Creative methods to overcome this challenge are needed.

Efficient use of our energy resources is also critical to success. As noted in the background paper on efficiency, railways in general have a fuel efficiency advantage over most other forms of transport, with the exception of interstate buses. With continually increasing energy prices and an associated increase in demand for passenger rail travel, it is important that we leverage our fuel efficiency advantage.

On a related note, if the supply of oil declines, as some predict (search the Internet for the words "peak oil" for some interesting reading), the use of alternative fuels for propulsion must be seriously examined. I would even suggest collaborative research with the U.S. Department of Energy.

9. Promote Cooperation-Sharing Assets.

Several years ago at a TRB session covering the topic of joint passenger–freight operation on shared corridors, a distinguished colleague with extensive experience in both passenger and freight rail remarked that "a passenger train operating on a freight railway network is like having your mother-in-law come to live with you." Given his credentials, experience, and the simple truth of the statement, I couldn't argue. Yet after some thought, I replied that "a freight train operating on our Northeast Corridor passenger railway network is like having Uncle Buck come and break down your bedroom door." The reality is that we are both here to stay, and we will both see increases in demand over shared networks.

Research and creative solutions must continue as we face the challenges and sometimes competing demands of joint passenger–freight operations on shared corridors. They have direct impacts on both capacity and operating efficiencies.

10. Keep People in the Forefront.

Last but not least, people are what passenger rail is about, whether the passengers or our employees. Passengers (their perception of our relative efficiency as a mode of transportation) and employees (through the efficiency that they exhibit in performing their daily assignments) will make or break us.

Our frontline employees in particular need to be part of the process to improve operating efficiencies; their daily decisions and actions have the biggest impact on our operations. They should no longer be viewed as simply the people we hire to solve our problems; they must see the problems as theirs as well. Achieving this transformation is no small task. It gets into the soft sciences that we engineers tend to avoid but most likely will yield the answers. My experience in the field has shown me that we have an often-untapped resource in our frontline employees. Most have the skills and experience that will help us achieve the goal of improving operating efficiencies; we need only take the time to engage them and listen.

In closing, I share a formula for success that has become essentially a mantra in Amtrak's engineering department:

$T = P + C^3$
Teamwork = Purpose + (Commitment × Communication × Collaboration)

It is effectively what we are doing in this workshop: As a team with a stated purpose, through our commitment to the rail industry, in an open communication of ideas, we are collaborating to develop an effective strategy for research to enhance rail network performance.

CONCLUDING ADDRESS

CONCLUDING ADDRESS

Railroads and Transportation

Our Future Options

Steven C. LaTourette, *U.S. Congress*

Since the beginning of this Congress, I've been privileged to serve as chairman of the House Transportation and Infrastructure Committee's Railroad Subcommittee. During this time, I've come to know the railroad industry well and to gain new respect for its importance to our nation's economy.

Even before I became chairman, I was aware of the importance of rail transportation. Coming from Ohio, that is probably natural. Fact is, you can't go far in Ohio without coming across a railroad track or a highway–rail grade crossing. I can assure you, I've spent my share of time waiting for a train to pass.

Ohio ranks fourth in the country in terms of rail mileage. Thanks to the thriving short-line industry, it ranks fifth in total number of railroads, with 35. It's also fifth in terms of both total rail mileage and rail employment. Its steel mills, auto manufacturers, power plants, and farmers all use rail as a vital part of their businesses.

Last year marked the 25th anniversary of the Staggers Act. It would be difficult to overstate the importance of that legislation and what it has meant to the railroad industry. Since 1980, rail productivity growth has been among the highest of all industries. From 1980 to 2004, the broadest measure of rail productivity—revenue ton-miles per constant dollar operating expense—increased 180%.

The vast majority of rail productivity gains were passed through to rail customers as lower rates. Measured by revenue per ton-mile, average inflation-adjusted rail rates fell 60% from 1980 to 2004. Although rates have increased some in the past year, that is still a remarkable achievement.

Since the Staggers Act, railroads have made tremendous safety gains. The train accident rate is down almost two-thirds since 1980, and the rate of employee casualties has been reduced by more than three-quarters since 1980.

Since the Staggers Act, short-line and regional railroads have come to play a vital role in our nation's freight transportation system. They operate more than 43,000 mi and employ more than 19,000 workers. These railroads preserve rail service and rail jobs that otherwise would have been lost.

Since the Staggers Act, the rail freight business has also grown by more than

70%. Plus, more than $360 billion of private money has been invested into infrastructure and equipment, and output per route mile has almost tripled. The revitalization of the private-sector freight railroad industry could not have come at a better time for the country. Our expanding economy is placing new demands on the transportation sector, but those demands could place new strains on the environment and on our own mobility. And that's where the railroad industry has so much to offer.

My understanding is that railroad fuel efficiency has improved by 72% over the past quarter century—72%. If highway fuel efficiency had improved by that much, then our whole nation would be better off. A freight train can move a ton of freight from Washington, D.C., to Boston, Massachusetts, on just 1 gallon of fuel. That's incredible. I also understand that today's locomotives are not only more fuel efficient but also pollute far less than those of a quarter century ago. That's a prime example of efficiency and the environment going hand in hand.

The other issue that has become so much more important over the past few years is mobility and congestion. Our economy requires efficient transportation. With the globalization of the economy, raw materials and finished products may have to move thousands of miles to get from seller to purchaser. Our transportation modes have done an incredible job of keeping pace with the demands placed on them. The United States truly does possess the finest, most adaptable, and most efficient freight transportation system in the world.

Yet this system is being seriously stressed. Highway congestion seems to grow worse by the day. We cannot possibly build or maintain enough highway lanes to accommodate the demands for freight and passenger volume. We also cannot afford to squander our fuel resources on just highways by using the least-efficient means of transportation for passengers and freight. Highway congestion already costs the economy tens of billions of dollars every year, and it is only getting worse.

Congestion leads to a huge waste of fuel. About 5.7 billion gallons of fuel were wasted due to traffic congestion in our 75 largest urban areas alone. To give you a visual of the amount of wasted fuel: Those 5.7 billion gallons would fill 570,000 gasoline tanker trucks. And lined up, those trucks would extend from New York to Las Vegas, Nevada, and back again.

The trucking industry says it needs thousands of new drivers but is having difficulty attracting them. Ships frequently are stacked off the ports of Los Angeles and Long Beach, California, awaiting their turns to be unloaded. And as railroads have attracted more and more business, they, too, have been overwhelmed at times.

Twenty-five years ago, people asked whether the railroads could survive. Today, they're asking whether the railroads can handle all the business coming their way. Railroads were the first means of land transportation able to move faster than a walking horse. A few of our large railroads now have so much business and so few employees and are so close to gridlock that a walking horse could sometimes pass a West Coast intermodal train.

Transportation Secretary Norman Mineta has likened the impact of congestion to that of a multi-billion-dollar hidden tax. We also know that the demand for freight transportation will continue to increase. The U.S. Department of Transportation projects a 69% increase by 2020. This means congestion will only get worse, unless steps are taken now to expand the capacity and efficiency of our transportation networks.

One of the great challenges we in Congress—and those who are in the transportation industry—face is how to answer this simple question: How do we prevent transportation from becoming the economy's choke point?

The transportation industry has developed numerous innovative ways of addressing this issue. One is intermodalism. Last year, trains working with trucks and steamship lines moved more than 11 million containers and trailers. Can you imagine how much worse our congestion would have been had these partnerships not developed? This year, intermodal volume exceeds 12 million trailers and containers—four times as much as 25 years ago. Railroads have entered into numerous operating agreements with each other to more efficiently use existing infrastructure through such actions as track sharing, directional running, and joint dispatching centers.

Railroads have embraced new technology. Locomotives are more powerful, individual freight cars can carry more cargo, and advanced communications and signaling systems have been deployed to permit more freight to travel over each mile of track. In addition, railroads have moved aggressively in other areas to meet increased demands. The industry's employment level was in a continuous downward spiral until 2 years ago. But since then, thousands of new employees have been hired, and employment levels have increased for the first time in decades. I understand that locomotive and freight car orders are at their highest levels in years and that a significant wait time now exists for the delivery of new rail freight equipment.

Railroads have announced plans to put a record $8.2 billion into capital improvements this year. This amount is in addition to the $30 billion that has been spent over the past 5 years to expand track capacity and improve signaling systems. Yet we all know that more must be done to increase transportation capacity.

For railroads, the challenge is especially acute. Railroads are among the most capital-intensive industries in the United States. Over the past 10 years, railroads put almost 18% of their revenues into capital improvements (whereas the average for U.S. manufacturing was 3.5%). Railroads also have significantly higher asset needs for each dollar of revenue than other industries. In 2004, the average for railroads was almost $3; the average for Fortune 500 industrial firms was less than half as much.

Increasing rail capacity will require billions more dollars in investment. New track costs an average of $1 to $2 million a mile. New locomotives cost more than $2 million each. Advanced train control systems will cost billions more. The railroad industry has almost an insatiable demand for capital.

Although highway and waterway investment dollars come from public sources, rail investment comes almost entirely from the private sector. Unfortunately for railroads, the return on investment has perennially trailed the industry's cost of capital. This situation has restricted the amount of capital that railroads can invest in capacity-increasing projects.

Hopefully, the gap between return on investment and the cost of capital was narrowed last year as record freight volume produced record railroad earnings. But it should be remembered that even if some railroads earned their cost of capital last year, they will have to continue to do so for an extended period if the amount of capital Wall Street will invest in railroads is to increase significantly.

Even with improved earnings, railroads probably will not be able to cover all of the infrastructure spending that must be done on their own. In fact, 3 years ago, the American Association of State Highway and Transportation Officials (AASHTO) identified a multibillion-dollar gap between what railroads could afford to invest and what it saw as the need for investment. But AASHTO also came up with a partial solution when it said that realizing the public benefits of a strong freight–rail system at a national level will require a new partnership among the railroads, the states, and the federal government (*1*). Public–private partnerships—in which railroads pay for the benefits they receive while the public pays for public benefits—are a good investment for both sides.

The benefits from freight rail are numerous. On average, railroads are three times more fuel efficient than trucks. The U.S. Environmental Protection Agency says that locomotives are also three times cleaner than trucks. One train can take the equivalent of 500 trucks off the highways, improving fuel efficiency, reducing pollution, easing highway congestion, and enhancing highway safety all at once. Numerous successful public–private partnerships provide a road map to the future.

The Alameda Corridor from the ports of Los Angeles and Long Beach reduced air pollution by nearly 1,500 tons in 2005 alone. It also reduced highway congestion by eliminating dozens of highway–rail grade crossings. On average, 47 trains now use the Alameda Corridor daily.

The FAST Corridor in the Pacific Northwest is another example, with transportation agencies, ports, cities, railroads, and trucking companies working together to streamline freight movements through the Puget Sound region. Other partnerships in California and North Carolina have provided new capacity so that both rail freight and rail passenger services can grow.

I think we in Congress made an important step forward by enacting SAFETEA-LU [the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users], the successor to what years ago was called the highway bill. I wish I could tell you what all those letters stand for, but some things are beyond the powers of a Congressman. I can tell you, however, that the LU part is named after Chairman Young's wife, so that one is easy to remember.

I know that most of the attention was focused on the highway spending it authorizes—and, of course, that is where most of the money goes. But it is much more and is very much an intermodal bill. Numerous provisions are important to railroads in that legislation. Among them are several that encourage public–private partnerships. It establishes a new category for programs of national significance. One of the beneficiaries will be the Chicago Region Environmental and Transportation Efficiency (CREATE), which will improve the fluidity of highway and rail movements through Chicago. The bill provides $100 million to get started on that project. Railroads have committed themselves to providing more than $200 million toward the final cost of $1.5 billion. I know more public funding will be required to see the project through to completion, but the bill provides a step toward securing those funds.

Also included in the legislation is more than $160 million for the Alameda Corridor East expansion, which will build on the demonstrated success of the Alameda Corridor in improving the flow of rail traffic from the ports of Los Angeles and Long Beach while reducing highway congestion. The final cost of this project is expected to be more than $1 billion, and this bill is a good first step toward securing that money.

The legislation also makes $90 million available for a project to increase clearances on a rail line between Virginia and Columbus, Ohio, permitting double stack trains to operate along that route, thereby reducing rail shipping distances by hundreds of miles. The legislation also continues the Section 130 program that has been so effective in reducing deaths at highway–rail grade crossings. Section 130 is not only continued but also substantially increased—from $165 million to $220 million annually. It has been proved that upgrade crossings mean fewer accidents, with the added benefit of improving the fluidity of the rail network.

Other elements of the legislation will have a positive impact on railroads. It expands eligibility for loans under the TIFIA program. We do love our acronyms in Washington, and TIFIA stands for the Transportation Infrastructure Finance and Innovation Act. In any event, TIFIA was expanded to include “a public freight rail facility or a private facility providing public benefit for highway users” and for “an intermodal freight transfer facility.”

The legislation authorizes what some call private activity bonds, which are tax exempt and specifically make truck–rail intermodal facilities eligible. Another provision authorizes $350 million annually for capital grants for rail line relocation projects. It also authorizes $35 billion in loans for Railroad Rehabilitation and Improvement Financing—or RRIF, another of our acronyms—and drops requirements that had made it difficult for many railroads to make use of the program.

SAFETEA-LU represents an important step in addressing the nation’s major transportation issues. But that’s all it is, one step. More remains to be done.

I know the railroads support a proposal to provide tax incentives for investment that increases capacity. In one sense, this proposal is a logical outgrowth of public–private partnerships, because it would allow the public to receive the benefits of increased rail capacity sooner than otherwise would be possible. It certainly is something we will look at closely.

Let me conclude by saying, the economy is going to continue to grow. And as it grows, additional demands will be placed on railroads and the other modes of transportation, posing new challenges to people in transportation and to people who set transportation policy. Of one thing I am certain: The country needs a growing and vibrant freight railroad system as part of an integrated transportation network. And I look forward to working with you to make sure that happens. Thank you.

REFERENCE

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Committee Member Biographical Information

Robert E. Gallamore, *Chair,* is recently retired from Northwestern University, where he was Director of the Transportation Center and Professor of Managerial Economics and Decision Sciences in the Kellogg School of Management. Before joining the university in August 2001, he was an executive on loan from Union Pacific Railroad to the Transportation Technology Center in Pueblo, Colorado, where he was Assistant Vice President of Communications Technologies and General Manager of the North American Joint Positive Train Control Program. He also served in several positions with the federal government, including Deputy Federal Railroad Administrator and Associate Administrator for Planning of the Urban Mass Transportation Administration. He recently served as Chairman of the TRB Committee on Freight Transportation Information Systems Security and the Committee for a Study of the Feasibility of a Hazardous Materials Transportation Cooperative Research Program. He was a member of the TRB Committee for a Review of the National Transportation Science and Technology Strategy and the Steering Committee for a Conference on Railroad Research Needs. He also served on the Transportation Panel of the Committee on Science and Technology for Countering Terrorism. He received a doctorate in political economy and government from Harvard University.

Christopher P. L. Barkan is Associate Professor in the Department of Civil and Environmental Engineering at the University of Illinois, where he is responsible for the university's railroad engineering research and academic programs. He also serves as Director of the Association of American Railroads (AAR) Affiliated Laboratory at the university. His research focuses on railroad safety and risk analyses, with particular emphases on derailment prevention, tank car design, and hazardous materials. He directs the AAR project that is developing a North American standard for a spill-proof fuel-delivery system for railroad locomotives. He chairs the TRB Rail Group, has been a member of the TRB Committee on Transportation of Hazardous Materials since 1996, has been a member of the Committee on Railroad Track Structure System Design since 1999, and served on the Committee for a Study of the Feasibility of a Hazardous Materials Transportation Cooperative Research Program. Before joining the university in 1999, he was Director of Risk Engineering in the AAR Safety and Operations Division. He continues as Deputy Project Director of the Railway Progress Institute–AAR Railroad Tank Car Safety Research and Test Project, a cooperative program of the tank car and railroad industries studying ways to improve tank car safety. He has a Ph.D. in biology from the State University of New York, Albany.

Anna M. Barry is Director of Railroad Operations at the Massachusetts Bay Transportation Authority (MBTA), where she has been involved in railroad operations since 1997. She was previously involved in MBTA transit vehicle maintenance and operations support, beginning in 1988. She also had specific field operations and management experience in freight railroad and passenger train movements at the Boston & Maine Corporation and in legislative affairs with the Commonwealth of Massachusetts. She serves as Chair of the American Public Transportation Association's (APTA) Commuter Rail Committee and Chair of APTA's Commuter Rail CEO Subcommittee. She holds an A.B. (English, 1975) from Boston College and a J.D. (1980) from Suffolk University Law School.

Vernon W. Graham is Vice President of Engineering Operations for the Canadian Pacific Railway and has held this position since 2003. Previously, he was Assistant Vice President of Engineering Operations and held progressive positions with Canadian Pacific Railway since starting in Engineering Services in 1973. He was a member of the Federal Railway Administration's Safety Advisory Committee from 1995 to 1999. He participated in the University of Michigan's Executive Program's Managing Critical Issues in 1993 and the McGill University's Ivey School of Business program in Leadership Development in 1998. He has a B.S. in government and pre-law from Montana State University.

Craig Hill was appointed to his current position of Vice President, Mechanical and Value Engineering, for the Burlington Northern and Santa Fe Railway Company (BNSF) in January 2002. He joined BNSF as Vice President and Chief Mechanical Officer in April 1999 from General Motors Corporation (GM) and was appointed Vice President, Engineering and Mechanical, for BNSF in August 1999. At GM his most recent position had been director of Processing Centers and Quality Assurance for GM's Service Parts Operations, GM's after-market warehousing and distribution operation. In this position, Hill managed more than 4,000 people working at four processing centers that distributed parts to 16 regional distribution centers.

Anson Jack is Director of Standards for the Rail Safety and Standards Board (RSSB) of the United Kingdom since 2004. Previously, he was Head of European Affairs from 2003 to 2004. RSSB is an industry-owned body that undertakes work in the areas of safety and standards to support all of the industry operators in Great Britain in fulfilling their legal responsibilities and to facilitate the resolution of cross-industry technical and economic issues. RSSB undertakes a program of research and development on behalf of the industry. Jack is responsible for the national set of railway standards, the interface between British and European standards, cross-industry committees that set all standards and explore the economically optimal solutions across railway system interfaces, and developing the rules for new signaling and radio systems. Before joining RSSB, he worked as Head of Strategy and Europe for Network Rail from 2002 to 2003. From 1993 to 2002, he was with Railtrack; his last position was Head of Strategy. From 1979 to 1993, he held various positions with British Rail, including National Business Manager. He also worked between 1995 and 1999 with the World Bank and the governments of Pakistan and Sri Lanka to explore and develop railway reform programs. He holds a B.A. and an M.A. from Oxford University.

David D. King recently retired as the Deputy Secretary for Transportation for the North Carolina Department of Transportation, where he was responsible for the department's five multimodal divisions: the Aviation Division, Bicycle and Pedestrian Transportation Division, Ferry Division, Public Transportation Division, and Rail Division. Previously, he held various positions, including Deputy Secretary for Transit, Rail and Aviation; Special Assistant to the Assistant Secretary for Management; and Director of the Public Transportation and Rail Division. He was Chair, States for Passenger Rail Coalition, 2001 through 2005. He holds a B.A. in economics from Davidson College and an M.B.A. from the University of North Carolina at Chapel Hill.

Charles R. Lynch is Vice President of Transportation for the Florida East Coast Railway since 1999. In this position, he has responsible charge of all system-related transportation functions, including network operations, train dispatching, crew dispatching, train scheduling, service design, and operating rules. Previously, he was Vice President of Maintenance from 1993 to 1999 with responsible charge of three departments—Communications and Signals, Maintenance of Way, and Maintenance of Equipment—as well as two subsidiary companies, Railroad Concrete Crosstie Corporation and Railroad Track Construction Company. He served as Chief Engineer of Communications and Signals before his appointment as Vice President in September 1993. His railroad career began in 1975 with the Penn Central Transportation Company (which later became Conrail). He has an A.S. and a B.S. in electronics engineering technology from Franklin University and an M.S. in electrical and computer engineering from the University of Massachusetts.

James McClellan is a Railroad Consultant. He formerly was Senior Vice President, Planning, at Norfolk Southern Corporation. He also worked with the Association of American Railroads, the Federal Railroad Administration, and Amtrak. He has been a member of the TRB Committee for the High-Speed Rail Innovations Deserving Exploratory Analysis Program and the Committee for the Study of Freight Capacity for the 21st Century. He holds a B.S. from the University of Pennsylvania.

Gerard McCullough is an Associate Professor in the Applied Economics Department and an Associate Member of the Graduate Faculty for the Economics Department at the University of Minnesota. He has developed and taught core courses in econometric analysis in the University of Minnesota's doctoral programs in applied economics and economics. He also developed a graduate certificate program in transportation studies to be administered by the Center for Transportation Studies. He served as a Special Assistant to the Federal Railroad Administrator (1977 to 1981). His methodological research interest focuses on the development and application of statistical techniques for the analysis of market structures and performance in transportation and other regulated industries, and his applied research interest focuses on the development and application of economic theories for the analysis of government regulation and procurement. McCullough holds an M.S. (transportation system, 1983) and a Ph.D. (civil engineering, 1993) from the Massachusetts Institute of Technology.

Audrey Milroy is System Engineer at QTEC, Inc. In this position, held since July 2004, she provides Command and Control Systems oversight functions to the Massachusetts Bay Transportation Authority (MBTA) and is technical liaison for the Greenbush Project with Amtrak, Massachusetts Bay Commuter Railroad Company, and MBTA. Before joining QTEC, she was Manager of the Engineering Department at Lockheed Martin Space Operations, from October 1999 to July 2004. Previously, she was Senior Director of Centralized Electric and Traffic Control (CETC) from February 1998 to October 1999 and Director of CETC from September 1995 to February 1998 with the National Railroad Passenger Corporation (Amtrak). As Senior Director of CETC, her duties included directing a comprehensive range of control center operations in Amtrak's Northeast Corridor, including strategic planning, operations planning, and budget and capital projections. Milroy previously worked at Science Applications International Corporation as a Project Manager/QA Systems Engineer from 1993 to 1995 and as Director of Transportation Systems from 1991 to 1993.

Thomas H. Rockwell is Professor Emeritus of Industrial and Systems Engineering at Ohio State University. He also is President of R&R Research, a human factors consulting firm. From 1975 to 1991, he supervised numerous railroad ergonomic projects for the Association of American Railroads and the Burlington Northern Railroad. His research areas include human factors engineering, transportation accident prevention, and human performance experimental design. He is a member of the Ergonomics Society and served as Fellow and Member of the Executive Council of the Human Factors Society of America between 1983 and 1986. He is an emeritus member of TRB's Committee on Vehicle User Characteristics and is an active member of its subcommittee on Railroad Operational Safety. He has a B.S. from Stanford University (1951) and an M.S. (1953) and a Ph.D. (1957) from Ohio State University.

James Stem is Alternate National Legislative Director of the United Transportation Union (UTU). He began his railroad career in 1966 as a trainman for the Seaboard Air

Line Railroad in Raleigh and joined the Brotherhood of Railroad Trainmen. He currently holds seniority as a Locomotive Engineer on CSX between Richmond, Virginia, and Abbeville, South Carolina. He worked part-time as a special UTU organizer from 1973 to 1976 and was elected as secretary–treasurer of Local 1129 in 1975. He has held the elected positions of local chairman and legislative representative and served as a delegate to five UTU International Conventions from 1979 to 1995. He was elected North Carolina State Legislative Director in 1984 and served in that position through September 1999. He was appointed Alternate National Legislative Director in April 1998 and was reelected to that position at the UTU Conventions in 1999 and 2003.

Gerhard A. Thelen is Vice President, Operations Planning and Support, for Norfolk Southern Corporation (NS). He is responsible for operations planning, policies, budgets, research and tests, and quality management functions. His previous positions with NS included Vice President, Mechanical, responsible for maintenance operations of locomotives and freight cars; Assistant Vice President, Mechanical; and Assistant Vice President, Research and Tests. Thelen previously was Assistant Vice President, Engineering, at Consolidated Rail Corporation, where he was responsible for design and construction of new track and facilities and managed R&D, including the company's effort in advanced train control. He is a member of the Association of American Railroads Research Committee. He holds an M.E. (industrial engineering, 1979) from Pennsylvania State University and is a member of the management committee for the North American Joint Positive Train Control Program, which is funded in part by the FRA Office of R&D and managed by Transportation Technology Center, Inc., staff.

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