Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads

Railway Technology Needs a 20-year Perspective

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AAR Research Priorities and the 20-year Technology Roadmap

- **Objective**
  - Frame a comprehensive rail technology roadmap
  - Include relevant technology
  - Minimize duplication
  - Foster coordinated efforts
  - Focus related research funding on railroad needs
- **Forecast technology development needs over a 20 year horizon**
  - Address efficiency, safety and service quality
  - Respond to capacity issues, environmental challenges, increased fuel efficiency and security concerns
  - Global Trends and Drivers translate into **Priority Technology Directions** in 5 areas
    - Rolling stock
    - Track and Structures
    - Motive Power
    - Operations and Train Control
    - Customer Service

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Technology Roadmap 2011

- **Global Trends and Drivers**
  - GDP growth through 2031at 2.5% annual average
  - Coal production will track electricity demand at 1% annual rate
  - Environmental Protection Agency (EPA) regulations for Tier 3, Tier 4 emissions; Greenhouse Gas (GHG) legislation
  - Rail passenger traffic increases
  - PTC implementation
  - Hazmat shipment security and spill prevention
  - Continued intermodal growth
  - Freight traffic growth in response to highway capacity, congestion and environmental issues
  - Electronics, inspection automation, information and communication technologies will predominate
  - Public-private partnerships (PPP) more challenging

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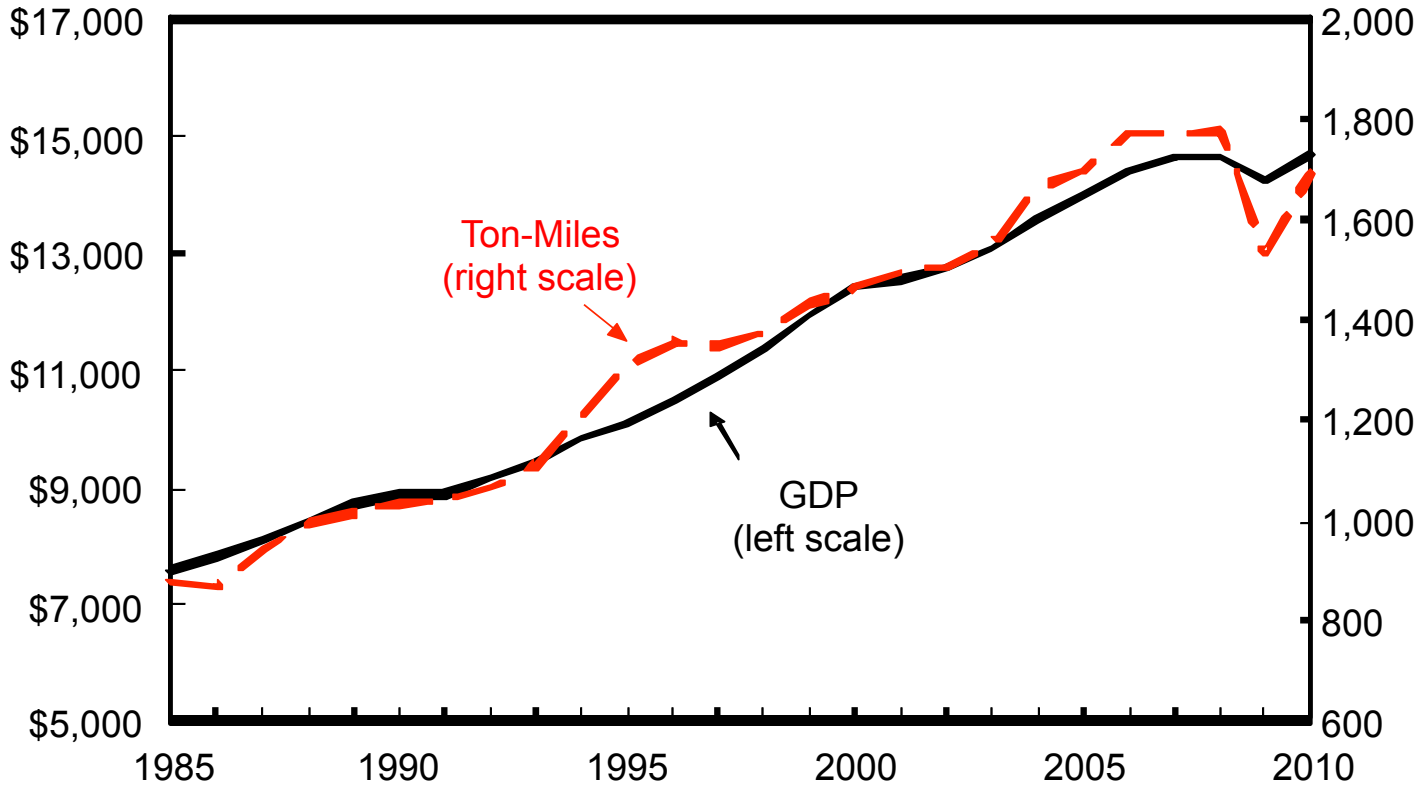
Gross Domestic Product (GDP) and Class I Revenue Ton-Miles

Chart 1: U.S. Real GDP vs. Class I Revenue Ton- Miles
(GDP in $ Billions, Ton -Miles in Billions)



GDP expressed in chained 2010 dollars. Source: AAR, U.S. Bureau of Economic Analysis

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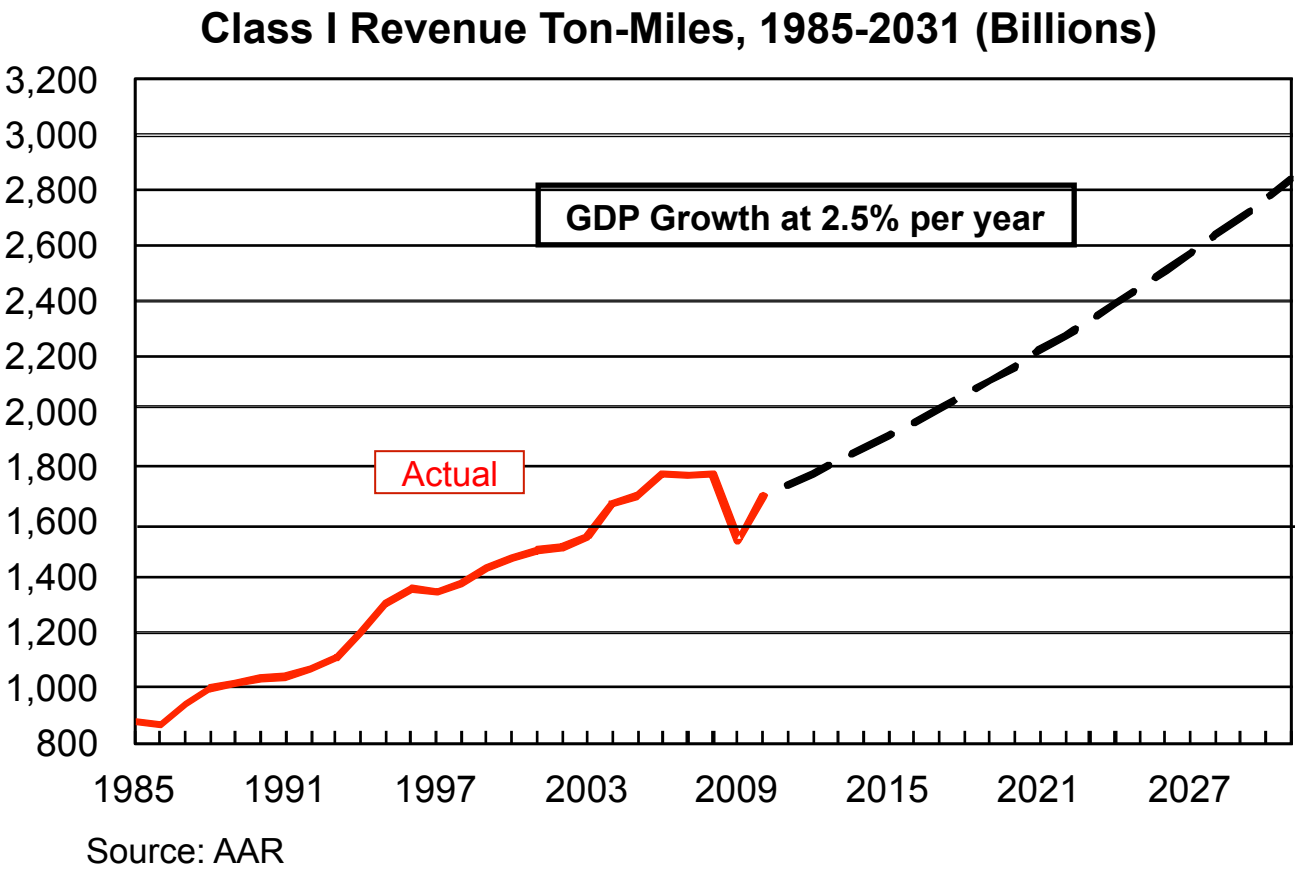
Class I Revenue Ton-Miles Projection



Source: AAR

Requires a 65% increase in capacity

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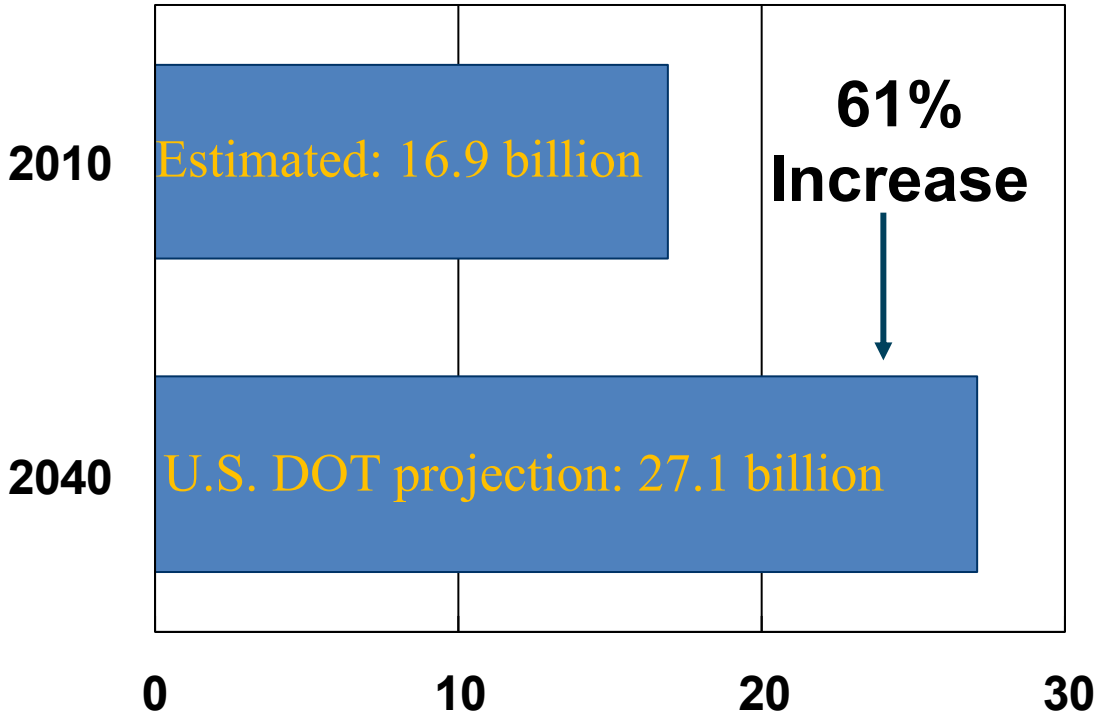
DOT Study Predicts Long-Term Demand for Freight Transportation Will Surge

Billions of Tons of Freight Transported in the U.S.



The U.S. DOT expects total U.S. freight movements to rise from around 16.9 billion tons in 2010 to 27.1 billion tons in 2040 – a **61% increase**.

Source: FHWA - *Freight Analysis Framework*, version 3, October 2010

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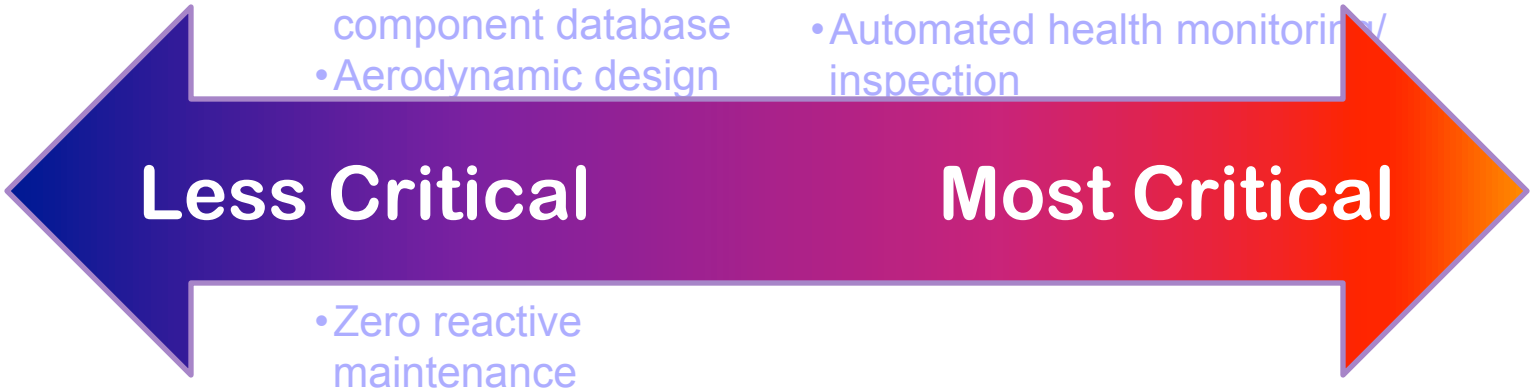
Technology Development Priorities

Industry Role	Useful	Necessary	Essential
High (80-100%)		• Wheel/rail interface management • Unified car & component database • Aerodynamic design	• Increased rolling stock & component life • Reduced in-service failures • Reduced accidents • Reduced life-cycle and total system cost • Automated health monitoring/ inspection
Medium (60-79%)	• Simplified car design	• Zero reactive maintenance • Improved braking capability including ECP braking • Improved asset tracking	
Low (<60%)			



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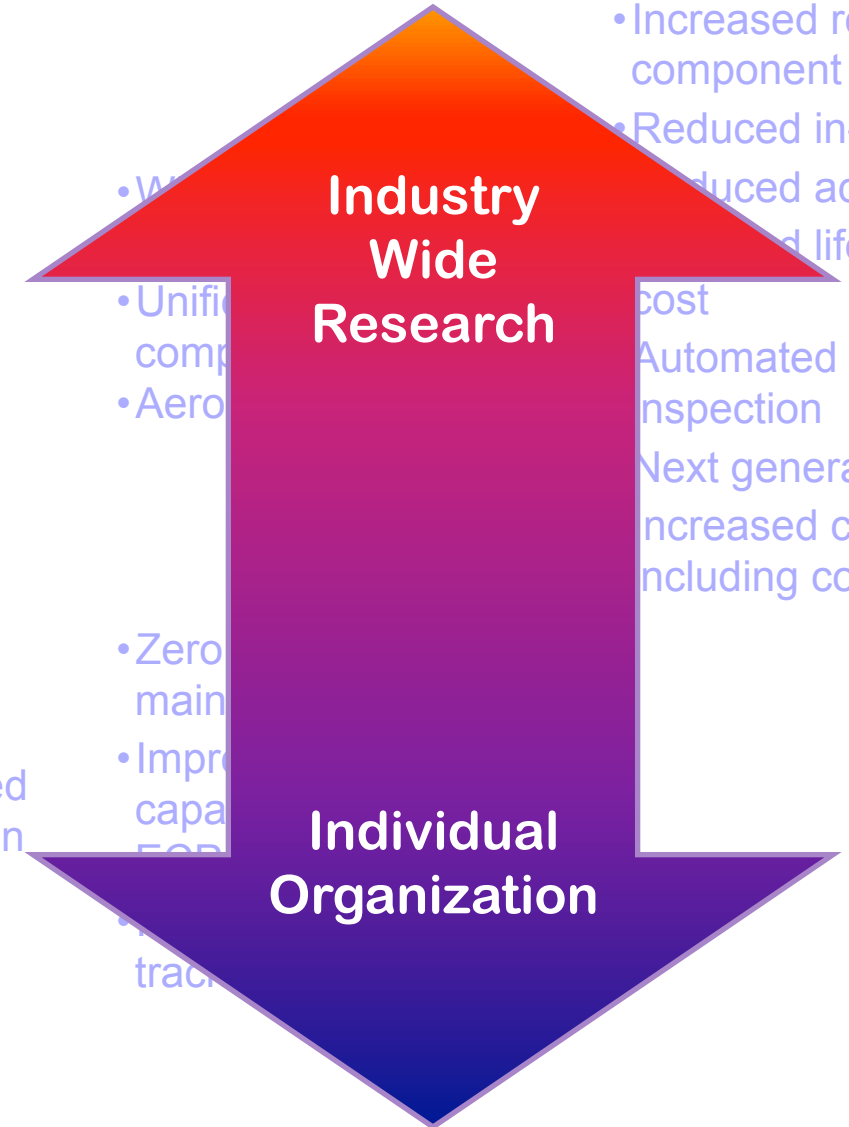
Technology Development Priorities

Industry Role	Useful	Necessary	Essential
High (80-100%)		• W • Unifi comp • Aero	• Increased rolling stock & component life • Reduced in-service failures duced accidents d life-cycle and total system cost Automated health monitoring/ nspection Next generation tank car ncreased car capacity & axle loads ncluding components & systems
Medium (60-79%)	•Simplified car design	• Zero main • Impr capa trac	
Low (<60%)			



Impact of Technology on Safety and Efficiency

- **Increasing asset lives**
  - Longer lasting track and rolling stock components
    - Increased wheel life
    - Increased rail life
    - Bridge life extension
- **Reductions in maintenance requirements allowing more time for train operations**
- **Proactive / predictive track and rolling stock maintenance**
- **More powerful, reliable and fuel efficient locomotives**
- **Integrated, automated track and train inspection systems**

Impact of Technology on Safety and Efficiency

- **Increasing train velocity**
  - Technologies to reduce time and distance required to start and stop trains and decrease spacing between trains
  - Reductions in train delays and service disruptions through elimination of unscheduled maintenance
  - Reductions in track outages and slow orders
  - Reductions in derailments – unplanned outages
  - Increased train speeds through special trackwork, across bridges and through terminal3

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Rolling Stock - Revised

Industry Role	Useful	Necessary	Essential
High (80-100%)		• Wheel/rail interface management • Unified car & component database • Aerodynamic design	• Increased rolling stock & component life • Reduced in-service failures • Reduced accidents • Reduced life-cycle and total system cost • Automated health monitoring/ inspection • Next generation tank car • Increased car capacity & axle loads including components & systems
Medium (60-79%)	• Simplified car design	• Zero reactive maintenance • Improved braking capability including ECP braking • Improved asset tracking	
Low (<60%)			

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Technology Directions – Rolling Stock

Industry Role	Essential	Strategic Research Initiatives
High (80-100%)	**Increased rolling stock & component life**	• Advanced Wheel Steels • High performance car coupling systems • Improved Brake systems and components • Root causes of Rolling Contact Fatigue • Wheel Defect Prevention
	Reduced in-service failures	• Automated Health Monitoring • Higher quality materials and designs •Fatigue and wear resistant wheel steels •Improved brake components •Improved car components and materials •Root causes of bearing failures

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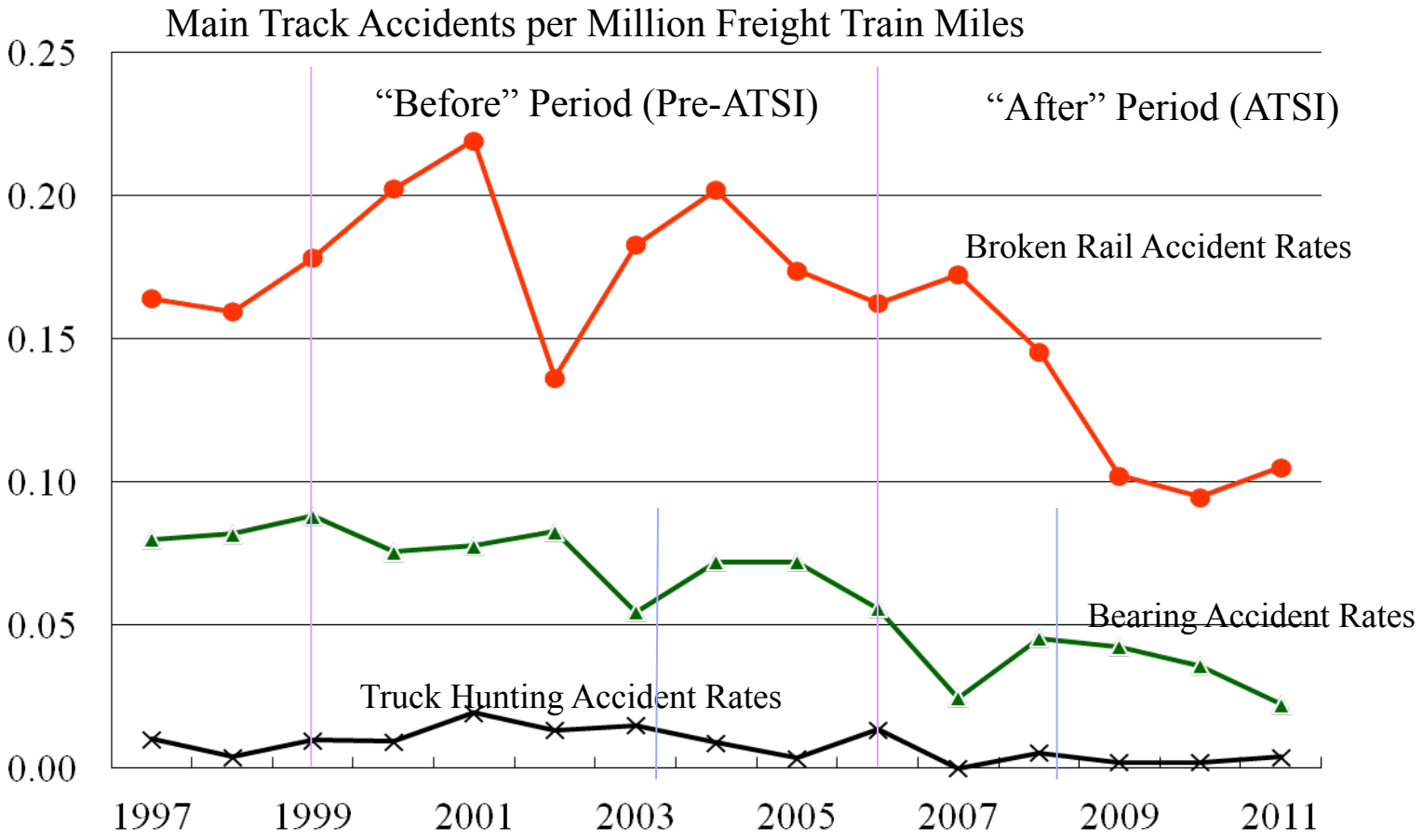
Technology Directions – Rolling Stock

Industry Role	Essential	Strategic Research Initiative
High (80-100%)	**Automated health monitoring/inspection and reduced accidents**	• Wayside detection • Advanced Technology Safety Initiative • Technology Driven Train Inspection • NDT of truck castings • Vehicle/based track and wheel/rail interface inspection
	Reduced life-cycle and total system cost	• Improved wheel steels, improved brakes, improved truck castings and drawgear components • Detector-based rolling stock maintenance
	Next generation tank car	• Advanced Tank Car Collaborative Research program

Technology Directions – Rolling Stock

Industry Role	Necessary	Strategic Research Initiative
High (80-100%)	Wheel/rail interface management	• Wheel/Rail Profile Designs and Maintenance • Automated Measurement / Management of the Wheel/Rail Interface • Friction Control • Root causes of Rolling Contact Fatigue • Effects of reverse rail cant on derailments
	Unified car and component database	• Data from RFID TAGS for car component identification • Car component condition • Wayside and Onboard detectors and operational information

ATSI has reduced main track accident rates from broken rail by 24%, from bearing defects by 44%, and from truck hunting by 69%



Source: AAR Analysis of FRA Train Accident and Train-Mile Data, 1997-2011, U.S. Class I Freight Railroads. Note: Years are Oct. 1 to Oct. 1

Track and Structures - Revised

Industry Role	Useful	Necessary	Essential
High (80-100%)	• Sustainable infrastructure development	• Low-impact track • Life extension for existing bridges under HAL • Longer lasting/cost-effective bridges • Decreased maintenance cost/ton-mile • Improved track/signal interface • Zero reactive maintenance	• Increased axle loads • Accident reduction • Onboard/in-track condition monitoring • Increased rail life • Reduced track component life-cycle cost
Medium (60-79%)		• Shared use corridors	• Track designs for smooth train velocities
Low (<60%)			

Technology Directions – Track & Structures

Industry Role	Essential	Strategic Research Initiative
High (80-100%)	Accident reduction	• Track Geometry-related Derailments • Broken Rail Derailment Reduction • Rail Joint-bar Failure Related Derailments • Track Gage Widening Derailments • Rail Weld Failure Related Derailments • Wheel/Rail Interface Related Derailments • Track Buckling Derailments
	Onboard/in-track condition monitoring	• Improved Rail Inspection • Rail Joint Bar Inspection • Rail Stress Measurement • Track Strength Measurement • Vehicle-based Track Geometry • Wheel/rail Interface Measurement

Technology Directions – Track & Structures

Industry Role	Essential	Strategic Research Initiative
High (80-100%)	**Increased rail life**	• Improved rail performance (Advanced Rail Steels) • Improved rail welding (Rail head repair, Improved welding tech. • Rail life extension (Friction control, Science-based rail grinding)
	Reduced track component life-cycle cost	• Improved Rail Performance and Life extension (Friction control) • Tie/fastener System Performance • Improved rail joining methods • Longer lasting turnout designs and materials • Improved Special Track Work foundation designs • Bridge life extension and maintenance • Hybrid composite bridge design

Technology Directions – Track & Structures

Industry Role	Necessary	Strategic Research Initiative
High (80-100%)	**Low-impact track**	▪ Track transition designs to reduce differential settlement ▪ Prototype diamond and frog foundation designs to minimize impact loads
	Longer lasting cost-effective bridges	▪ Hybrid composite bridge spans ▪ High performance concrete spans ▪ Bridge life extension using UIT of welded components ▪ Reducing stress state by removing bridge joints
	Decreased maintenance cost/ton-mile and zero reactive maintenance	▪ FAST and Revenue service tests of new and improved components ▪ Friction management and rail profile designs ▪ Running surface profile designs for special trackwork ▪ Rail stress management ▪ Improved maintenance to extend lives of IJs and bridges

Technology Directions – Track & Structures

Industry Role	Necessary	Strategic Research Initiative
High (80-100%)	Increased axle loads	▪ FAST/HAL tests on track components ▪ HAL Revenue service tests at three "Megasites" ▪ HAL track substructure research (GPR) ▪ FAST steel and concrete bridge tests ▪ HAL effects on economics ▪ Advanced bridge designs and materials ▪ Bridge performance monitoring
	Improved track/signal interfaces	▪ Track signal wire attachment best practices ▪ FAST evaluation of prototypes ▪ Lighter train effects on toss of shunt

Rail Research Benefits

Rail Life Increase 1994-2008

Curvature (Degrees)	1994 (MGT)	2008 (MGT)	Percent Increase
0	1458	1972	35%
1	1054	1539	46%
2	642	1289	101%
3	577	992	72%
4	508	882	74%
5	443	775	75%
6	392	671	71%
7	362	580	60%
8	371	574	55%
9	346	480	39%
10	326	410	26%

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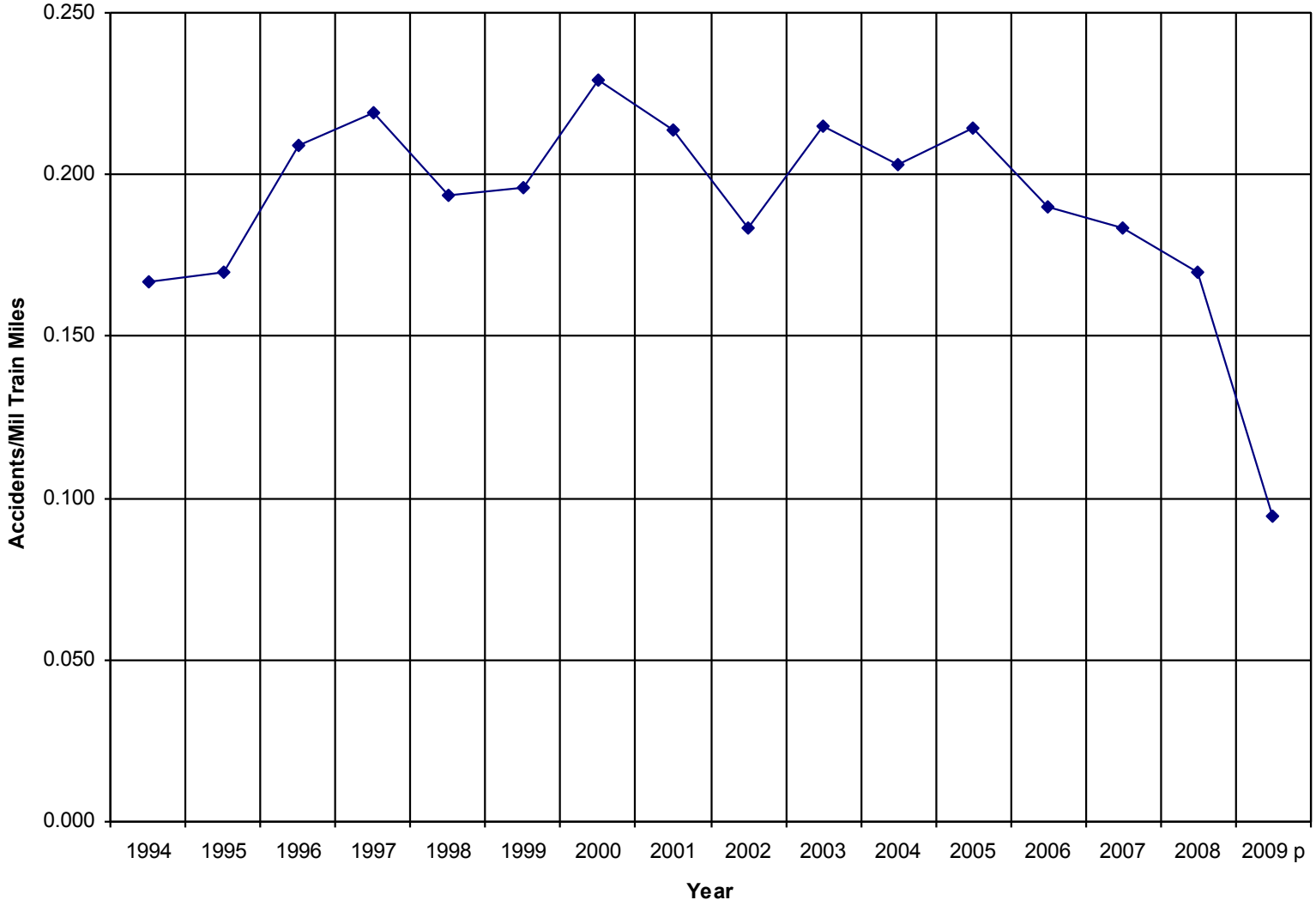
Track-Related Accident Rates for Mainline Class I Track



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Technology Directions - Motive Power

Industry Role	Useful	Necessary	Essential
High (80-100%)			• Energy harvesting and storage systems • Emissions control technologies • Advanced power systems with reduced emissions • Energy efficiency in train systems • Cost-effective alternative fuels • Improved locomotive reliability
Medium (60-79%)		• ECP brakes	
Low (<60%)	• Remote control locomotive equipment	• Vehicle configuration & maintenance reporting • Onboard health monitoring • Longer lasting component designs & materials	• Improved thermal efficiency in locomotive engines

Technology Directions - Operations and Train Control

Industry Role	Useful	Necessary	Essential
High (80-100%)		• Traffic monitoring systems & ETA projections* • Interchange monitoring/ timely execution* • Standalone wireless mandatory directive • Broken rail detection • Right-of-way, tunnel & bridge intrusion detection systems • Narrowband radio • Wireless applications	• Integrated operations planning/management systems** • Overlay train control systems • Higher performance data radio • Completion of operational-friendly braking enforcement algorithms for both freight & passenger operations • Reliable PTC components • Distributed power • Assisted train handling
Medium (60-79%)	•Automated train operations	• Moving block** • Asset tracking • RCL implementation	•Standalone train control**
Low (<60%)	• Resource management systems*	• Transportation planning systems* • Dispatching systems* • Blocking/ yard management* • Pacing/train handling*	

***Components of "integrated planning & management systems"**

****Contributes to increasing network velocity**

Technology Directions - Customer Service

Industry Role	Useful	Necessary	Essential
High (80-100%)		• Traffic monitoring systems*	• Reduced in-service failures+ • Reduced accidents+ • Improved asset tracking* • Integrated operations planning/ management systems* • Fulfillment of government needs in safety & security areas • Enhanced & integrated railroad transaction management systems
Medium (60-79%)	•Asset utilization*	• Integrated customer rail spot information/Smart train technology	• Customer mobile applications
Low (<60%)		• Interchange visibility & timely execution	• Integration of customer & railroad shipment information

*** Note: Detail in other sections: +Rolling Stock, Track & Structures, Motive Power, *Operations**

Roadmap Summary

- **Priority Capacity Challenge**
  - Can be met with coordinated infrastructure expansion and technology-driven productivity improvements
- **Limited capital funds**
  - Will provide for somewhat less than half the physical plant investments needed
- **Technology implementation and investments**
  - Will be able to meet better than half the increased capacity demand
- **New plant investments**
  - Will also benefit from technology-driven productivity gains
- **Coordinated / collaborative research by stakeholders**
  - Will be required to realize the technology developments envisioned in the plan