



National Integrated Railway Safety Research Priorities (NIRSRP)

Driving Next-Generation Research for Smart, Safe, Sustainable, and Future-Ready Railway Infrastructure

A Flagship Research Framework of the Rail Safety Research and Development Forum (RSRDF)

A Unit of the All India Rail Safety Council (AIRSC)

The National Integrated Railway Safety Research Priorities (NIRSRP) is the principal research framework of the Rail Safety Research and Development Forum (RSRDF), a unit of the All India Rail Safety Council (AIRSC). It establishes a comprehensive roadmap for multidisciplinary research that supports the continuous advancement of railway safety, infrastructure resilience, operational excellence, digital transformation, and sustainable transportation.

The framework identifies strategic research priorities that will shape the future of railway engineering, intelligent infrastructure, advanced technologies, asset management, and transportation innovation. It serves as a common platform for researchers, engineers, railway professionals, policymakers, academic institutions, technology providers, industry partners, and international organisations to collaborate on solutions that address the evolving challenges of modern railway systems.

With India's railway sector undergoing rapid transformation through High-Speed Rail, Metro Rail expansion, Dedicated Freight Corridors, Digital Railways, Artificial Intelligence, predictive maintenance, smart infrastructure, and sustainable mobility, the need for coordinated, research-driven innovation has never been greater.

The National Integrated Railway Safety Research Priorities provide a structured and future-oriented approach for developing technologies, engineering solutions, safety standards, operational strategies, and evidence-based policies that contribute to a safer, smarter, greener, and globally competitive railway ecosystem.

The programme aligns with the national priorities of Viksit Bharat 2047, Atmanirbhar Bharat, Digital India, Make in India, PM Gati Shakti, the National Rail Plan, and the United Nations Sustainable Development Goals (SDGs).

Vision

To establish India as a global centre of excellence in railway safety research by creating an integrated research ecosystem that drives technological innovation, engineering excellence, operational safety, and sustainable infrastructure development.

Mission

The National Integrated Railway Safety Research Priorities aim to:

Define strategic research directions for future railway development.

Promote multidisciplinary collaboration across engineering, technology, management, and public policy.

Encourage indigenous innovation and scientific excellence.

Accelerate the adoption of advanced digital technologies.

Improve infrastructure reliability and operational resilience.

Support evidence-based decision-making and international best practices.

Build a knowledge-driven railway sector capable of meeting future transportation demands.

Strategic Research Priorities

Smart Railway Infrastructure Engineering

Research on intelligent railway infrastructure incorporating advanced materials, smart sensors, digital monitoring, resilient engineering, and integrated asset management to improve long-term safety, durability, and operational performance.

High-Speed Rail Infrastructure

Development of engineering standards, track technologies, bridge systems, signalling integration, vibration control, and maintenance strategies to support safe, reliable, and high-performance high-speed rail operations.

Metro Rail Systems

Research focusing on urban rail mobility, automated operations, passenger safety, energy efficiency, intelligent stations, and integrated multimodal transportation solutions for rapidly growing metropolitan regions.

Structural Health Monitoring

Application of advanced sensing technologies, fibre optic systems, AI-based diagnostics, and real-time monitoring for continuous assessment of bridges, tunnels, viaducts, stations, and other critical railway structures.

Intelligent Asset Management

Development of lifecycle asset management frameworks using predictive analytics, digital engineering, condition-based maintenance, and risk-informed investment planning to optimise infrastructure performance.

Artificial Intelligence Applications

Research into Artificial Intelligence and Machine Learning for predictive maintenance, intelligent signalling, operational optimisation, anomaly detection, decision-support systems, and safety risk management.

Digital Twins

Development of digital replicas of railway infrastructure and operational systems to enable simulation, performance analysis, predictive maintenance, engineering optimisation, and strategic planning.

Internet of Things (IoT)

Integration of connected sensors and smart devices to provide real-time monitoring of railway assets, environmental conditions, equipment performance, and operational safety.

Predictive Maintenance

Research on advanced maintenance methodologies using AI, IoT, digital twins, and analytics to predict equipment failures, reduce maintenance costs, minimise downtime, and enhance system reliability.

Robotics and Automation

Application of robotic technologies for infrastructure inspection, maintenance operations, tunnel assessment, hazardous environment monitoring, automated construction, and emergency response.

Drone Technologies

Research into unmanned aerial systems for efficient inspection of railway tracks, bridges, overhead electrification, stations, construction projects, and remote infrastructure.

Satellite Monitoring

Use of satellite imagery, remote sensing, and geospatial technologies for infrastructure surveillance, land management, environmental monitoring, disaster assessment, and strategic planning.

Railway Cyber-Physical Systems

Development of secure and integrated cyber-physical systems connecting digital platforms with physical railway assets to improve automation, operational control, safety, and cybersecurity.

GIS and BIM Applications

Research on Geographic Information Systems (GIS) and Building Information Modelling (BIM) for infrastructure planning, digital asset management, lifecycle engineering, project execution, and operational decision-making.

Climate Adaptation

Engineering research addressing the impacts of climate change through resilient infrastructure design, flood protection, landslide mitigation, heat-resistant materials, and adaptive maintenance strategies.

Promotion of environmentally responsible engineering practices, green construction materials, renewable energy integration, circular economy principles, and sustainable infrastructure management.

Energy-Efficient Infrastructure

Research into energy optimisation, regenerative technologies, renewable energy systems, smart power management, and low-carbon railway infrastructure to improve environmental performance.

Sustainable Engineering

Safety Risk Analytics

Development of advanced analytical models for identifying, evaluating, predicting, and mitigating safety risks through data science, artificial intelligence, and quantitative risk assessment.

Infrastructure Lifecycle Management

Research focused on planning, design, construction, operation, maintenance, renewal, and disposal of railway assets to maximise long-term performance, safety, sustainability, and cost-effectiveness.

Future Mobility Systems

Exploration of emerging transportation technologies including autonomous rail systems, connected mobility, intelligent transportation networks, multimodal integration, hydrogen propulsion, battery-electric rail systems, and next-generation passenger mobility solutions

.Cross-Disciplinary Research Framework

The National Integrated Railway Safety Research Priorities encourage collaboration across multiple disciplines, including:

- Railway Engineering
- Civil Engineering
- Mechanical Engineering
- Electrical Engineering
- Electronics and Communication
- Artificial Intelligence
- Computer Science
- Cybersecurity
- Data Science
- Environmental Engineering
- Disaster Management
- Transport Planning
- Urban Mobility
- Economics
- Public Policy
- Human Factors Engineering
- Safety Management
- Sustainability Studies

Research Implementation Strategy

The framework supports:

- National Collaborative Research Projects
- Pilot Demonstration Programmes
- Technology Validation and Field Trials
- Innovation Incubation
- Industry-Academia Partnerships
- International Research Collaboration
- Centres of Excellence
- Research Fellowships
- Technical Publications
- Standards Development
- Policy Research
- Knowledge Repositories
- Capacity Building and Professional Development

Expected Outcomes

The National Integrated Railway Safety Research Priorities are designed to deliver:

- World-class railway safety research.
- Intelligent and resilient railway infrastructure.
- Faster adoption of advanced technologies.
- Stronger operational safety and reliability.
- Improved asset performance and lifecycle management.
- Sustainable and climate-resilient railway systems.
- Enhanced passenger and workforce safety.
- Increased indigenous innovation and technological self-reliance.
- Greater collaboration between government, academia, and industry.
- Internationally benchmarked engineering and safety practices.

National Significance

The future of railway transportation depends on the ability to integrate engineering excellence with digital innovation, scientific research, sustainability, and collaborative knowledge. By defining clear national research priorities, RSRDF provides a strategic framework that supports the continuous evolution of India's railway sector while addressing future mobility challenges and strengthening national infrastructure.

These priorities will help create a railway ecosystem that is safer, smarter, more efficient, environmentally responsible, and globally competitive.

The Rail Safety Research and Development Forum (RSRDF), under the All India Rail Safety Council (AIRSC), is committed to advancing research that delivers practical, scalable, and impactful solutions for the railway sector.

Through the National Integrated Railway Safety Research Priorities, we seek to unite researchers, engineers, academic institutions, technology companies, industry leaders, policymakers, and international partners in a shared mission to shape the future of railway safety and infrastructure.

Together, we are building a national research ecosystem that promotes innovation, strengthens resilience, enhances operational excellence, and contributes to India's vision of Viksit Bharat 2047—creating a railway network that is recognised worldwide for its safety, intelligence, sustainability, and engineering excellence.

Framework Motto

**"RESEARCH WITH PURPOSE • INNOVATION WITH IMPACT •
SAFETY WITHOUT COMPROMISE."**

"ADVANCING KNOWLEDGE TO BUILD THE RAILWAYS OF TOMORROW."

ALL INDIA RAIL SAFETY COUNCIL (AIRSC)
Committed to Safer Railways, Stronger Nation

RAIL SAFETY RESEARCH & DEVELOPMENT FORUM (RSRDF)
RESEARCH | INNOVATION | EXCELLENCE
Building Future-Ready Rail Safety Systems
for an Atmanirbhar Bharat and Viksit Bharat 2047

Dr. R. Padmanabhan
Chairman
All India Rail Safety Council (AIRSC)

SAFE TRACKS • STRONG NATION • UNITED INDIA

www.railsafety.co.in

Icons: SAFETY (Our Core Commitment), INNOVATION (Driving Future Solutions), RESEARCH (Advancing Knowledge), COLLABORATION (Strengthening Partnerships), SUSTAINABILITY (Building a Resilient Future), CYBER SECURITY, AI, SAFETY FIRST.



NATIONAL INTEGRATED RAILWAY SAFETY

— RESEARCH PRIORITIES (NIRSRP) —

Driving Next-Generation Research for **Smart, Safe, Sustainable,** and Future-Ready Railway Infrastructure

INDIAN RAILWAYS

LIFE LINE TO OUR NATION



SAFE RAILWAYS



SMART TECHNOLOGIES



SUSTAINABLE FUTURE



STRONGER NATION

STRATEGIC RESEARCH PRIORITIES



Smart Railway Infrastructure Engineering
Intelligent infrastructure, advanced materials, smart sensors, digital monitoring, resilient engineering and asset management.



High-Speed Rail Infrastructure
Engineering standards, track technologies, bridge systems, signalling integration, vibration control and maintenance strategies.



Metro Rail Systems
Urban rail mobility, automated operations, passenger safety, energy efficiency, smart stations and multimodal integration.



Structural Health Monitoring
Advanced sensing, fibre optics, AI diagnostics and real-time monitoring of bridges, tunnels, viaducts and stations.



Intelligent Asset Management
Predictive analytics, condition-based maintenance, risk-informed planning and lifecycle asset optimisation.



Artificial Intelligence Applications
AI & ML for predictive maintenance, intelligent signalling, optimisation, anomaly detection & decision support.



Digital Twins
Digital replicas for simulation, performance analysis, predictive maintenance and strategic planning.



Internet of Things (IoT)
Connected sensors & smart devices for real-time monitoring of assets, environment and operations.



Predictive Maintenance
AI, IoT, digital twins & analytics to predict failures, reduce costs, minimise downtime and enhance reliability.



Robotics and Automation
Robots for inspection, maintenance, tunnel assessment, hazardous monitoring, construction and emergency response.



Drone Technologies
UAVs for inspection of tracks, bridges, OHE, stations and construction projects.



Satellite Monitoring
Satellite imagery & remote sensing for surveillance, land management, environmental monitoring and disaster assessment.



Cyber-Physical Systems
Secure cyber-physical systems integrating digital platforms with physical assets for automation, control & cybersecurity.



GIS & BIM Applications
GIS & BIM for planning, digital asset management, lifecycle engineering and operational decision making.



Climate Adaptation
Resilient infrastructure, flood protection, landslide mitigation, heat-resistant materials and adaptive maintenance.



Sustainable Engineering
Green materials, renewable energy, circular economy and sustainable infrastructure management.



Energy-Efficient Infrastructure
Energy optimisation, regenerative tech, renewable energy integration, smart power management and low-carbon infrastructure.



Safety Risk Analytics
AI & data science for identifying, evaluating, predicting and mitigating safety risks.



Infrastructure Lifecycle Management
Planning, design, construction, operation, maintenance, renewal and disposal for long-term performance.



Future Mobility Systems
Autonomous rail, connected mobility, ITNs, multimodal integration, hydrogen, battery-electric and next-generation passenger solutions.

CROSS-DISCIPLINARY RESEARCH FRAMEWORK

- | | |
|-----------------------------|---------------------------|
| Railway Engineering | Environmental Engineering |
| Civil Engineering | Disaster Management |
| Mechanical Engineering | Transport Planning |
| Electrical Engineering | Urban Mobility |
| Electronics & Communication | Economics |
| Artificial Intelligence | Public Policy |
| Computer Science | Human Factors Engineering |
| Cybersecurity | Safety Management |
| Data Science | Sustainability Studies |



RESEARCH IMPLEMENTATION STRATEGY

- ✓ National Collaborative Research Projects
- ✓ Pilot Demonstration Programmes
- ✓ Technology Validation and Field Trials
- ✓ Innovation Incubation
- ✓ Industry-Academia Partnerships
- ✓ International Research Collaboration
- ✓ Centres of Excellence
- ✓ Research Fellowships
- ✓ Technical Publications
- ✓ Policy Research
- ✓ Knowledge Repositories
- ✓ Capacity Building and Professional Development
- ✓ Standards Development
- ✓ Knowledge Repositories



SAFE INFRASTRUCTURE



SMART OPERATIONS



SUSTAINABLE TRANSPORT



INNOVATION FOR NATION



EXCELLENCE IN SAFETY