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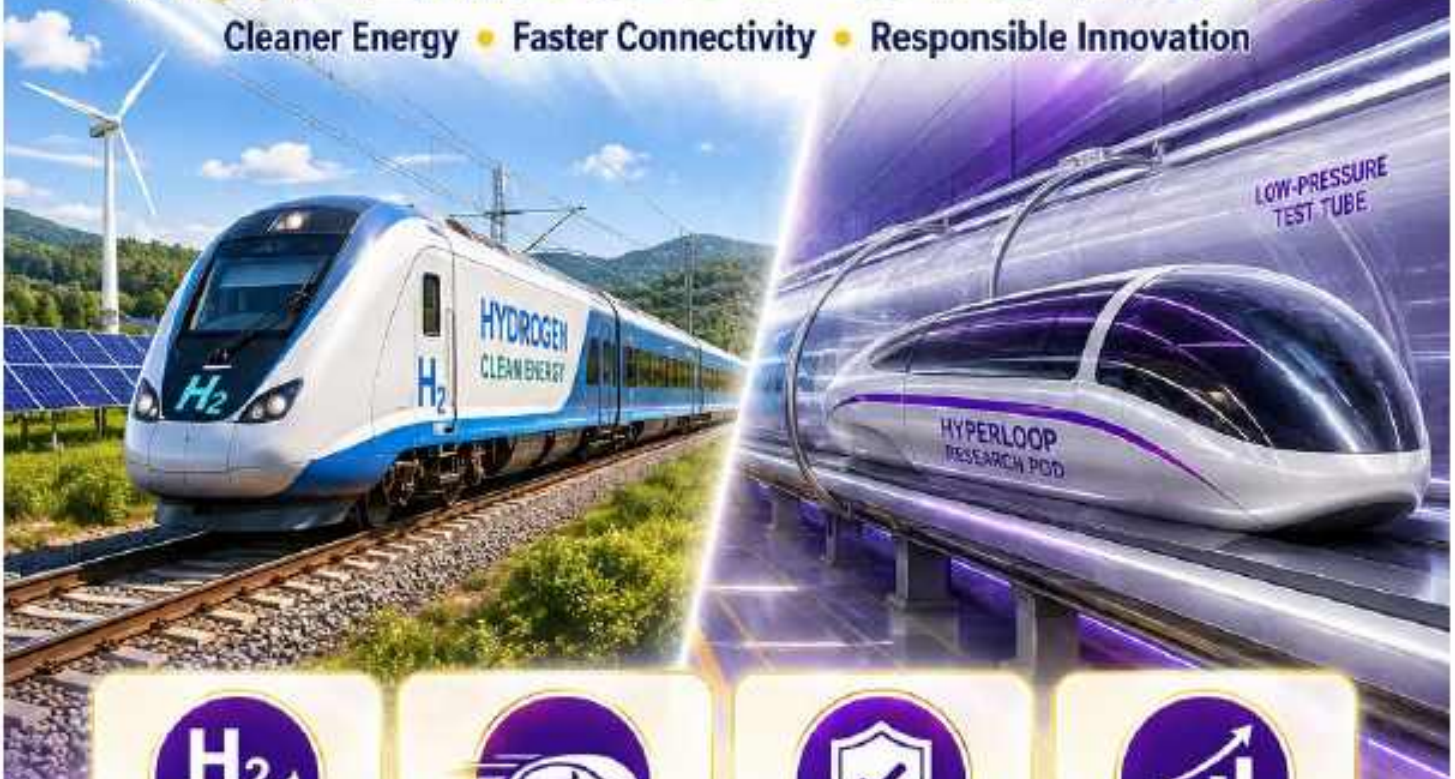
FUTURE TECHNOLOGIES: HYDROGEN TRAINS & HYPERLOOP SYSTEMS

Cleaner Energy • Faster Connectivity • Responsible Innovation



Clean Propulsion
Zero tailpipe emissions for a greener tomorrow.

High-Speed Research
Exploring next-gen mobility through rigorous testing and innovation.

Safety First
Robust testing, standards and risk assessment at every stage.

Evidence-Led Progress
Data-driven decisions for reliable, scalable and public-value outcomes.

Hydrogen trains advance established railways; hyperloop explores a new transport mode. Both require rigorous testing, safety assessment and public-value evaluation.

Innovation With Evidence. Mobility With Responsibility.

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Vision 2047 • Sustainable Mobility • Research • Safety

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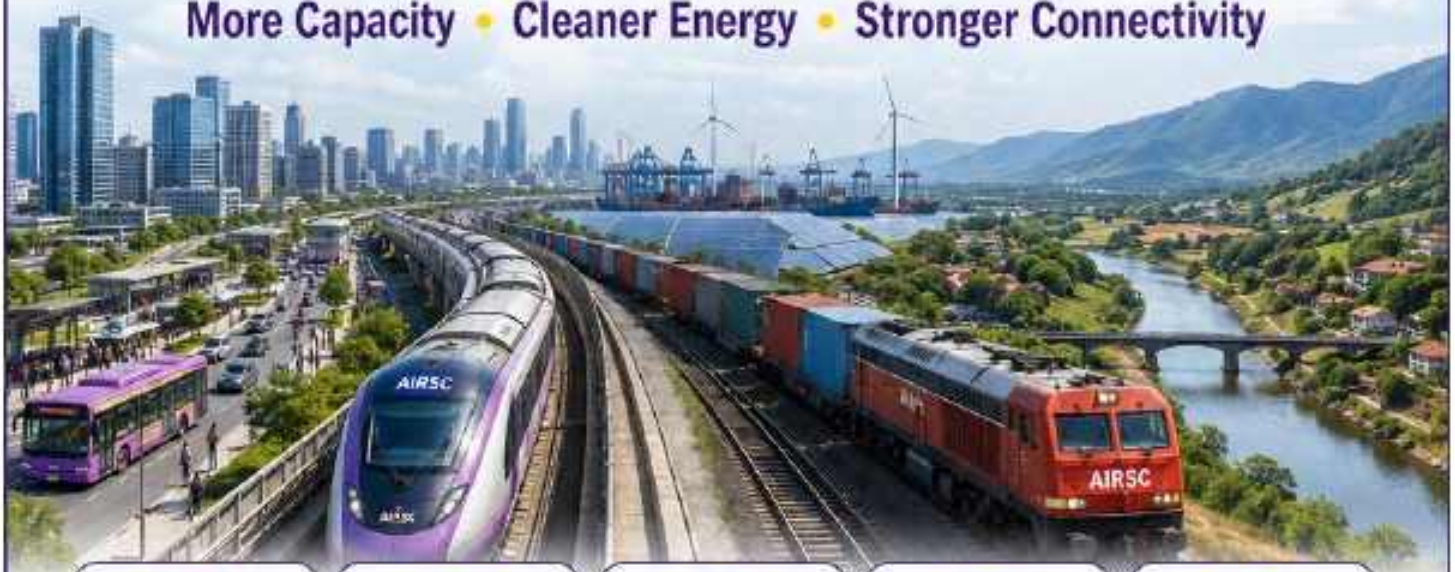
WHY INDIA NEEDS NEXT-GENERATION MOBILITY

More Capacity • Cleaner Energy • Stronger Connectivity



- Growing Passenger Demand
- Efficient Freight Movement
- Remote-Route Solutions
- Lower Lifecycle Emissions
- Integrated Public Value

DECISION FRAMEWORK

SAFETY • COST • CAPACITY • ENERGY • ACCESSIBILITY • INTEGRATION

KEY MESSAGE

New technology must solve a genuine transport need—not pursue speed or novelty alone.

Choose the Right Technology for the Right Route.

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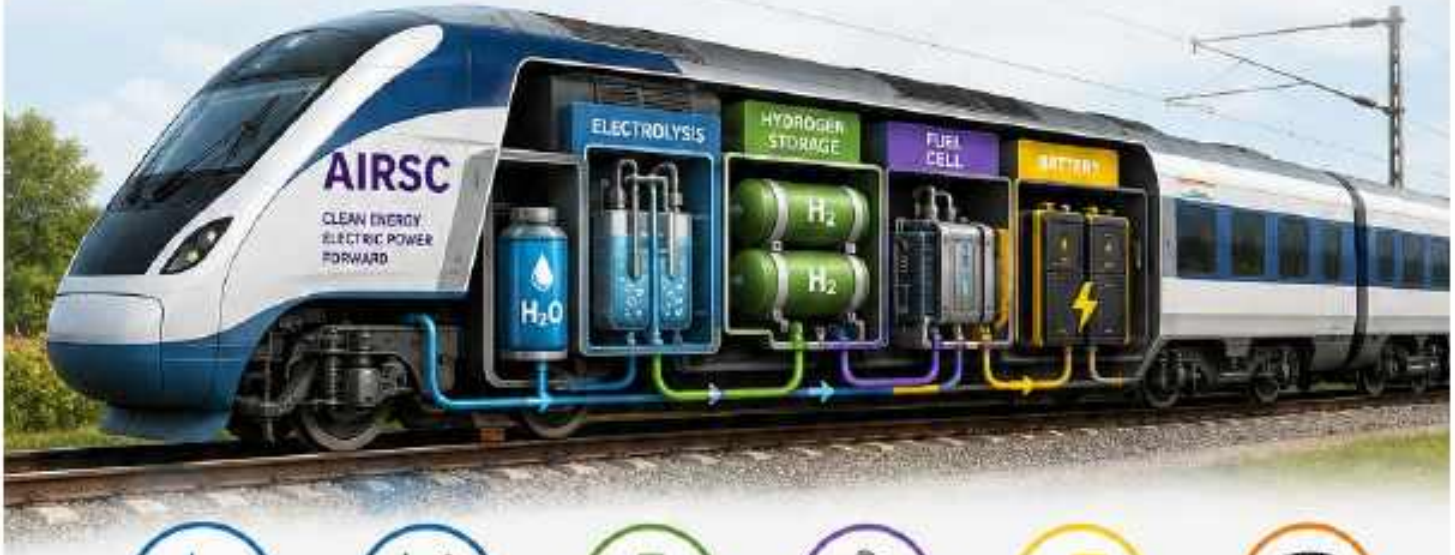
HOW HYDROGEN TRAINS WORK

Green Hydrogen • Fuel Cells • Batteries • Electric Traction



GREEN ELECTRICITY + WATER → ELECTROLYSIS → HYDROGEN STORAGE → FUEL CELL → ELECTRICITY → TRACTION MOTORS

Fuel Cell: Continuous Power

Provides steady electricity for sustained operation.

Battery: Acceleration Support

Delivers high power for acceleration and peak demands.

Regenerative Braking

Recovers energy during braking and stores in batteries.

Water & Heat: Direct By-products

Clean water and heat are the only by-products.

Hydrogen is an energy carrier.
Its environmental value depends on how the hydrogen is produced.

Clean Energy In. Electric Power Forward.

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GREEN HYDROGEN, REFUELLING & ENVIRONMENTAL VALUE

Renewable Production • Safe Storage • Efficient Operations

Renewable Electricity
Clean power from solar & wind

Water & Electrolysis
Purified water split into hydrogen

Compression & Storage
Compressed & stored safely under control

Scheduled Refuelling
Procedure-based safe refuelling

Lifecycle Assessment
Measure, monitor & improve impact

INFRASTRUCTURE SAFETY BY DESIGN

GAS DETECTION | VENTILATION | FIRE PROTECTION | CONTROLLED ACCESS | EMERGENCY ISOLATION

KEY MESSAGE

Zero tailpipe carbon does not automatically mean zero lifecycle emissions—green production and efficient infrastructure are essential.

Produce Cleanly. Store Safely. Operate Responsibly.

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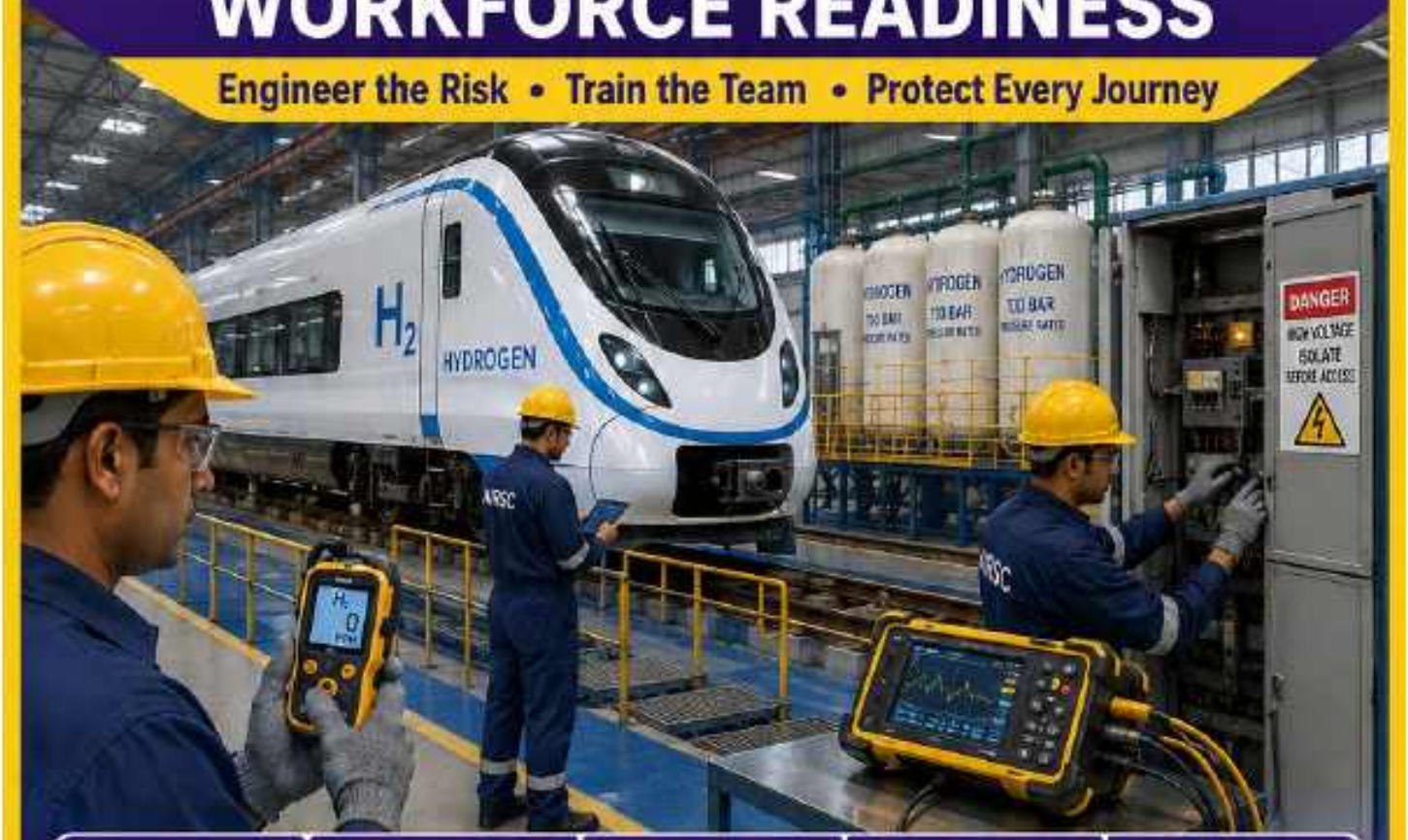
HYDROGEN SAFETY, MAINTENANCE & WORKFORCE READINESS

Engineer the Risk • Train the Team • Protect Every Journey



Leak Detection	Ventilation	Pressure-Rated Tanks	Automatic Shutdown	Emergency Training

WORKFORCE COMPETENCIES

HYDROGEN HANDLING • HIGH-VOLTAGE SAFETY • FUEL-CELL DIAGNOSTICS
FIRE RESPONSE • SAFE EVACUATION

KEY MESSAGE Hydrogen can be used safely when specialised engineering controls, procedures and competency standards are rigorously applied.

New Energy Demands New Skills and Uncompromising Safety.

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AIRSC SERIES
RESEARCH POSTER

UNDERSTANDING HYPERLOOP & INDIA'S RESEARCH ECOSYSTEM

Low-Pressure Tube • Research Pod • Propulsion • Control

REDUCED AIR RESISTANCE
Low-pressure tube minimizes drag for high efficiency

LOW-FRICTION SUPPORT
Maglev or low-friction guidance for stable and smooth travel

LINEAR ELECTRIC PROPULSION
Precise, scalable thrust for safe acceleration

AUTOMATED CONTROL
Real-time monitoring, sensors and control for safety and stability

RESEARCH PATHWAY

COMPONENT TESTS
Validate materials, subsystems and technologies

→ **INTEGRATED POD**
Assemble and test pod systems as a unit

→ **LONGER TEST TRACK**
Evaluate in extended tube for performance and reliability

→ **HIGH-SPEED TRIALS**
Progressively higher speeds under controlled conditions

→ **CERTIFICATION EVIDENCE**
Generate data for safety case and standards

KEY MESSAGE: A test facility builds engineering capability; it is not yet a commercial passenger corridor.

Research Boldly. Test Rigorously. Claim-Only What Evidence Proves.

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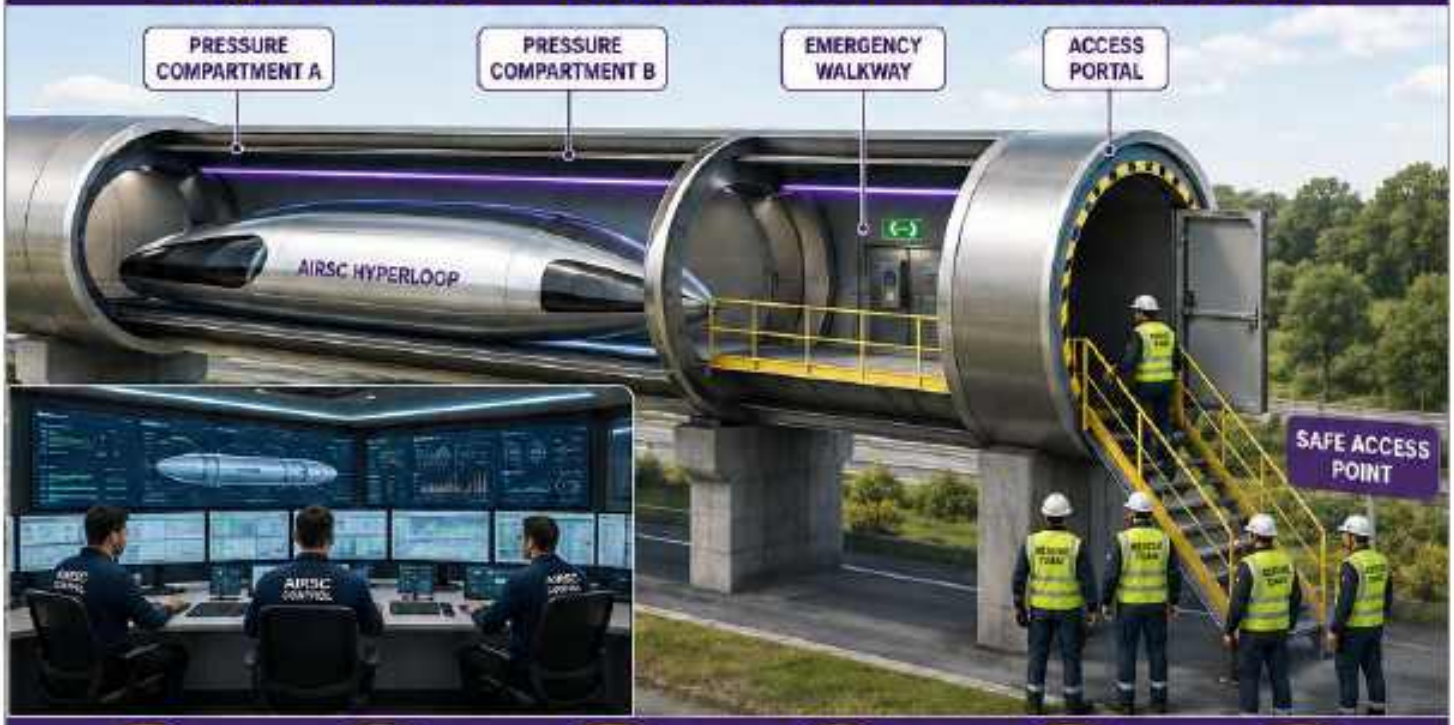
HYPERLOOP ENGINEERING, PASSENGER SAFETY & EVACUATION

Design for Failure • Protect the Cabin • Reach Every Incident



Tube Integrity | Safe Braking | Pressure Loss | Fire & Smoke | Power Failure | Medical Emergency

SAFETY ARCHITECTURE

PREVENTION → DETECTION → ISOLATION → SAFE STOP → EVACUATION → RESCUE ACCESS

Public operation requires validated design, independent certification and effective evacuation under realistic worst-case conditions.

HUMAN FACTORS:
Comfortable Acceleration • Ventilation • Communication • Accessible Evacuation

No Speed Is Valuable Without Proven Safety.

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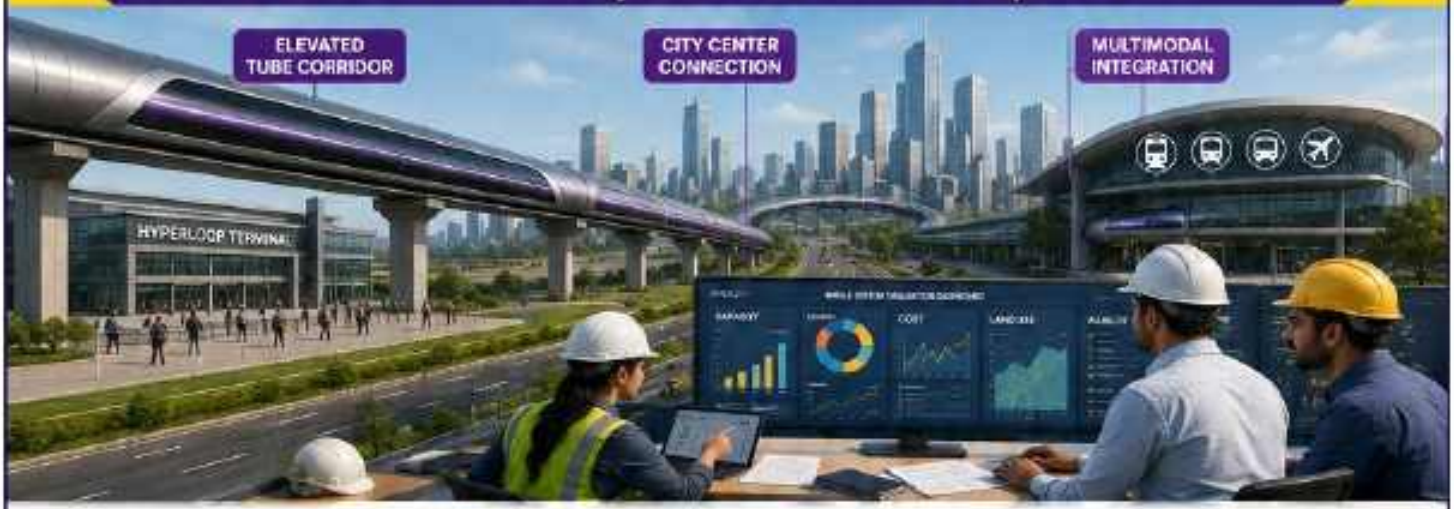
HYPERLOOP: CAPACITY, ENERGY, LAND, COST & VIABILITY

Measure the Whole System—not Maximum Speed Alone



COMPARE THE WHOLE SYSTEM	HYPERLOOP	HIGH-SPEED RAIL	UPGRADED RAIL	AIR TRANSPORT
Passenger Capacity (PPHPD)				
Total Journey Time				
Full-System Energy (per passenger-km)				
Land Use & Alignment Impact				
Lifecycle Cost (₹ per passenger-km)				
Resilience & Reliability				
Maturity & Implementation Risk				

1 PASSENGER CAPACITY

- Can the system move the required passengers per hour per direction?
- Can terminals process passengers safely?

2 TOTAL JOURNEY TIME

- What is door-to-door time including access, waiting, transfers and egress?
- Does it outperform proven alternatives?

3 FULL-SYSTEM ENERGY

- What is total energy per passenger-km across the entire system?
- Is it better than high-speed rail and air?

4 LAND & ALIGNMENT

- What is the total land required and land-use impact?
- Can emergency access reach the entire route?

5 LIFECYCLE COST

- What is the total cost over the full life cycle?
- Can demand support the investment?

KEY EVALUATION QUESTIONS

- Can terminals process passengers safely?
- Can emergency access reach the entire route?
- Can demand support the investment?
- Does it outperform proven alternatives?

Theoretical performance is not commercial proof.
Decisions require verified test data and consistent comparison with high-speed rail, upgraded rail and air transport.

Public Investment Demands Public Value.

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HYDROGEN TRAINS & HYPERLOOP:
DIFFERENT TECHNOLOGIES, DIFFERENT ROLES

Compare Purpose • Infrastructure • Maturity • Safety

HYDROGEN TRAINS	HYPERLOOP
Purpose: Cleaner traction	**Purpose:** Proposed ultra-high-speed transport
Infrastructure: Existing tracks + hydrogen facilities	**Infrastructure:** Entirely new tube and terminals
Maturity: Prototype and pilot operation	**Maturity:** Research, testing and demonstration
Best Fit: Selected non-electrified or specialised routes	**Possible Fit:** Long-term selected intercity corridors
Priority: Green fuel, reliability and safe refuelling	**Priority:** Engineering proof, evacuation, regulation and viability

Hydrogen changes how a train obtains energy.
Hyperloop proposes a new transport system.

Evaluate Each Technology on Its Real Role and Evidence.

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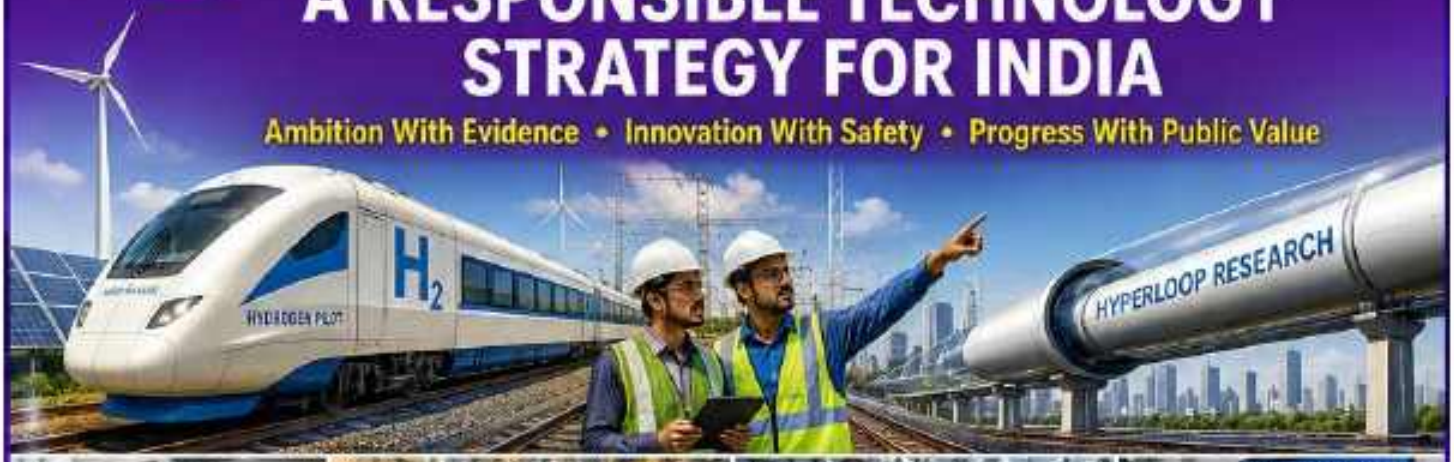
A RESPONSIBLE TECHNOLOGY STRATEGY FOR INDIA

Ambition With Evidence • Innovation With Safety • Progress With Public Value



1. **Pilot Before Scale**
2. **Independent Safety Assessment**
3. **Lifecycle Evaluation**
4. **Transparent Comparison**
5. **Domestic Capability**
6. **Standards & Regulation**

ROADMAP FOR RESPONSIBLE ADOPTION

RESEARCH → VALIDATE → PILOT → MEASURE → CERTIFY → DEPLOY RESPONSIBLY

India should not adopt technology because it appears futuristic. It should select solutions that are safe, sustainable, affordable and genuinely suited to national needs.

VISION ZERO PLEDGE

Every Innovation Tested • Every Risk Understood • Every Decision Accountable • Every Life Valued

Building Future Mobility for Viksit Bharat 2047

Research • Skills • Safety Culture • Responsible Innovation