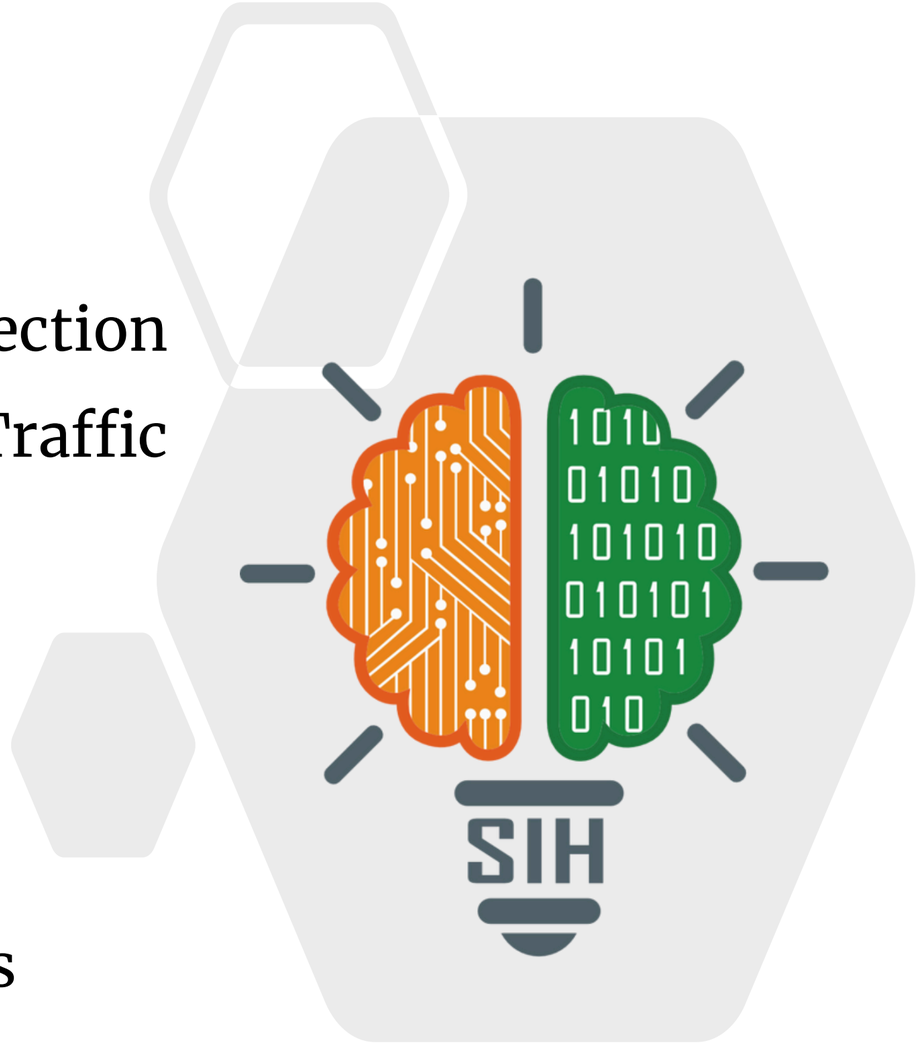
SMART INDIA HACKATHON 2025

TITLE PAGE

- **Problem Statement ID –** 25022
- **Problem Statement Title –** Maximizing Section Throughput Using Al-Powered Precise Train Traffic Control
- **Theme –** Transportation & Logistics
- **PS Category –** Software
- **Team ID –** 102098
- **Team Name (Registered on portal) –** RailOptimus



IDEA TITLE

Idea/Solution

- An **AI-powered decision**- assists section controllers in **real-time train scheduling** and **precedence decisions.**
- Uses **operations research algorithms** to generate conflict-free, optimized schedules under **multiple constraints** (track availability, train priorities, platform capacities, and safety rules.)
- Integrates a **predictive AI engine** (reinforcement learning) to forecast **train delays, ETAs, and dynamic speed guidance.**
- Provides **interactive scenario simulations**, allowing controllers to test **"what-if" situations.**
- **Dashboard-centric approach**: Visualizes live train states, performance KPIs, and route analytics through interactive maps, charts, and a user-friendly interface.
- **Rapid re-optimization engine** adapts instantly to real-time disruptions (breakdowns, delays, weather).
- **Modular architecture** allows seamless integration with existing railway control systems, making the solution production-ready while retaining flexibility for future scaling and additional ML-driven features.

Problem Resolution

- Replaces manual, intuition-based decisions with **precise, data-driven recommendations.**
- **Resolves conflicts** across multiple trains, priorities, and infrastructure constraints.
- Resolves conflicts at **complex junctions & platforms** to prevent cascading delays.

Unique Value Preposition

- **AI Predictor Card**
  Delay/ETA insights directly on dashboard.
- **Interactive Map & Simulation**
  Visual exploration + rapid scenario testing.
- **Disruption-Ready**
  Re-optimizes schedules under emergencies
- **Polished UX**
  Responsive, intuitive, mobile-aware interface.
- **Backend-Ready**
  Easy integration with REST APIs without UI changes.

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TECHNICAL APPROACH

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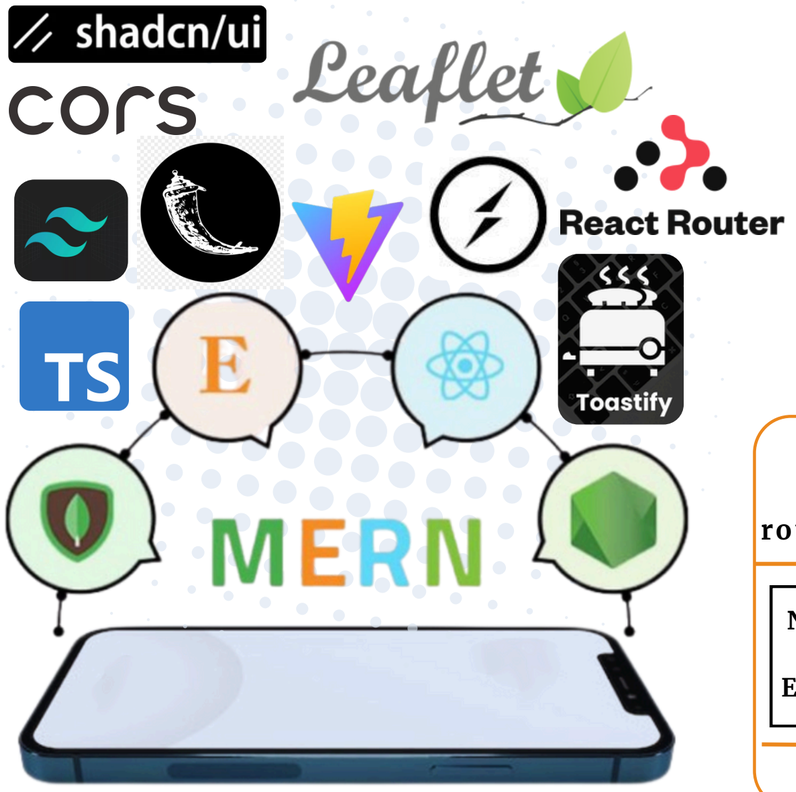
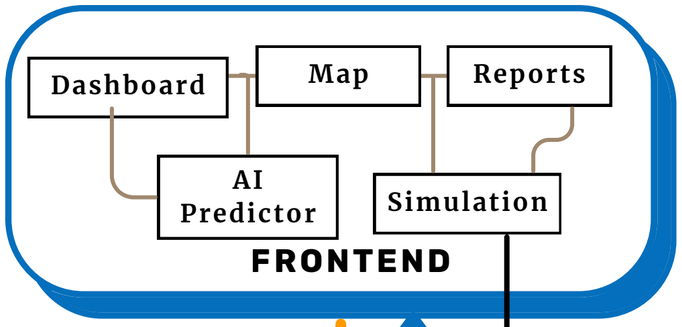
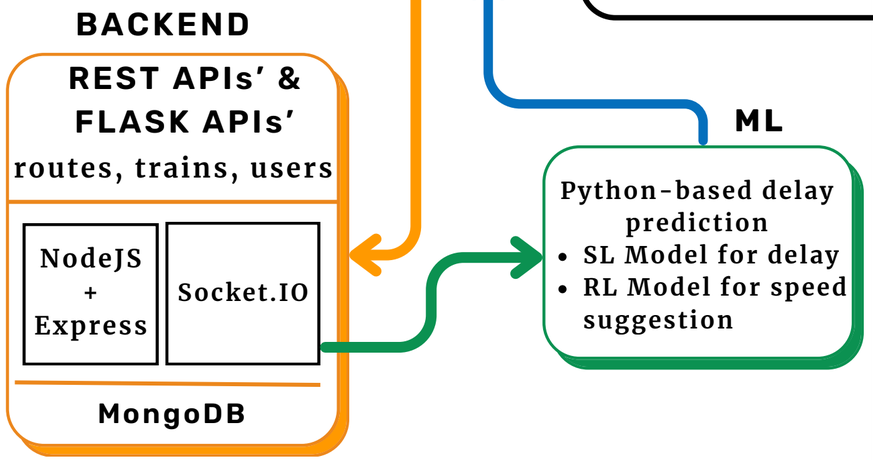
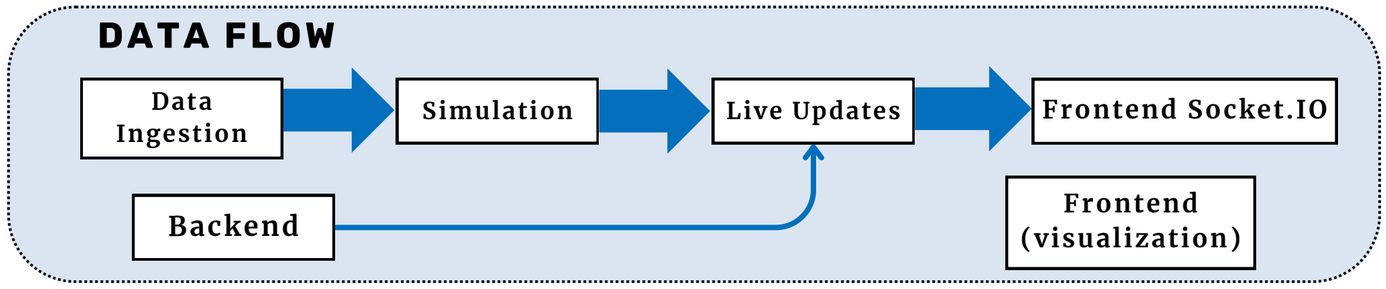
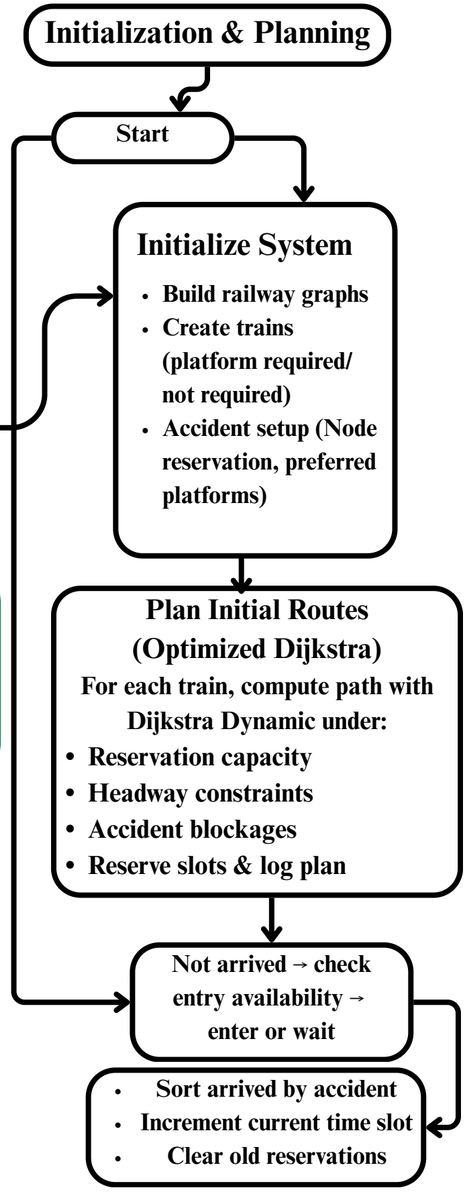
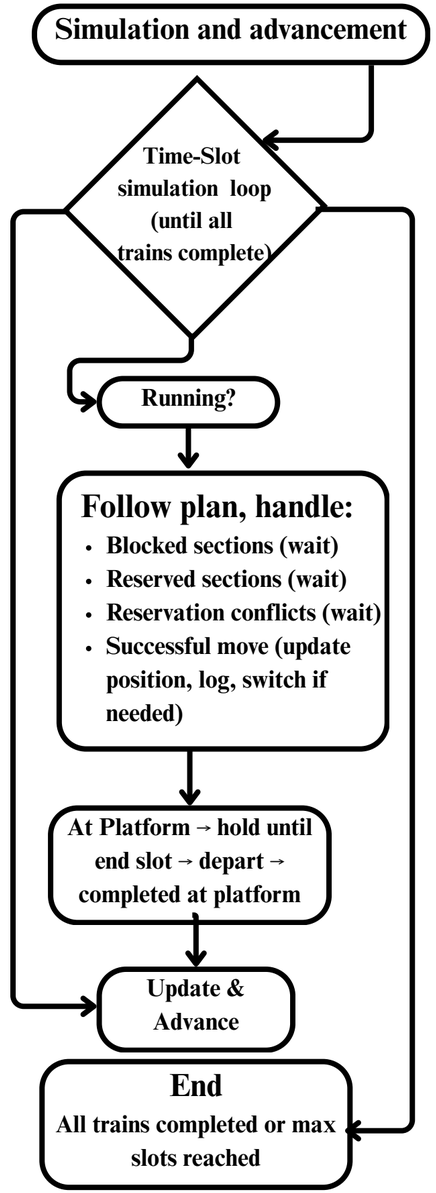












FEASIBILITY AND VIABILITY

Feasibility Analysis

Technical:

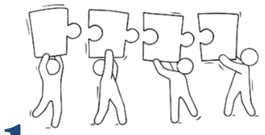
- **Enterprise-grade stack** (React + TypeScript, Node.js + Express, MongoDB, Python ML)
- **Real-time decision engine** powered by Socket.IO enables continuous conflict resolution under live traffic conditions.
- **AI-powered forecasting & reallocation** (SL + RL) directly addresses combinatorial scheduling challenges of mixed-priority trains.
- **Microservices architecture** allows independent scaling of optimization, visualization, and data services across sections.
- **API-first integration** with signalling & TMS ensures smooth coexistence with existing Indian Railways infrastructure.

Financial:

- **Open-source foundation** → zero licensing costs, sustainable in the long run.
- **Leverages existing IT infrastructure** of Indian Railways, minimizing upfront CAPEX.
- **Automation-driven efficiency** lowers recurring operational costs compared to manual-only control.

Market / Operational:

- **Seamless adoption** with controller workflows → minimal training required.
- **Throughput maximization** under congestion by dynamically prioritizing various trains.
- **Scenario simulation & what-if dashboards** for both daily control decisions and higher-level policy analysis.
- **High adoption potential** due to tangible KPIs.
- **Audit trails & reporting** ensure accountability and continuous operational improvement.



Challenges

- **Technical**: Real-time conflict resolution between mixed-priority trains accross limited tracks and platforms.

- **Financial:** Maintenance costs at the scale of Indian Railways' vast network.

- **Operational / Market:** User training for controllers, adoption resistance, regulatory compliance with safety norms.

Strategies to overcome

Operational: Intuitive UI, scenario simulations for training, secure APIs for seamless integration.

Algorithms: AI/ML for ETA prediction, OR-based optimization for schedules, conflict-aware simulation engine.

Financial: Cloud deployment for reduced infrastructure cost, gradual rollout.

Technical: Modular microservices, scalable WebSocket layer, offline-first fallback.

IMPACT AND BENEFITS

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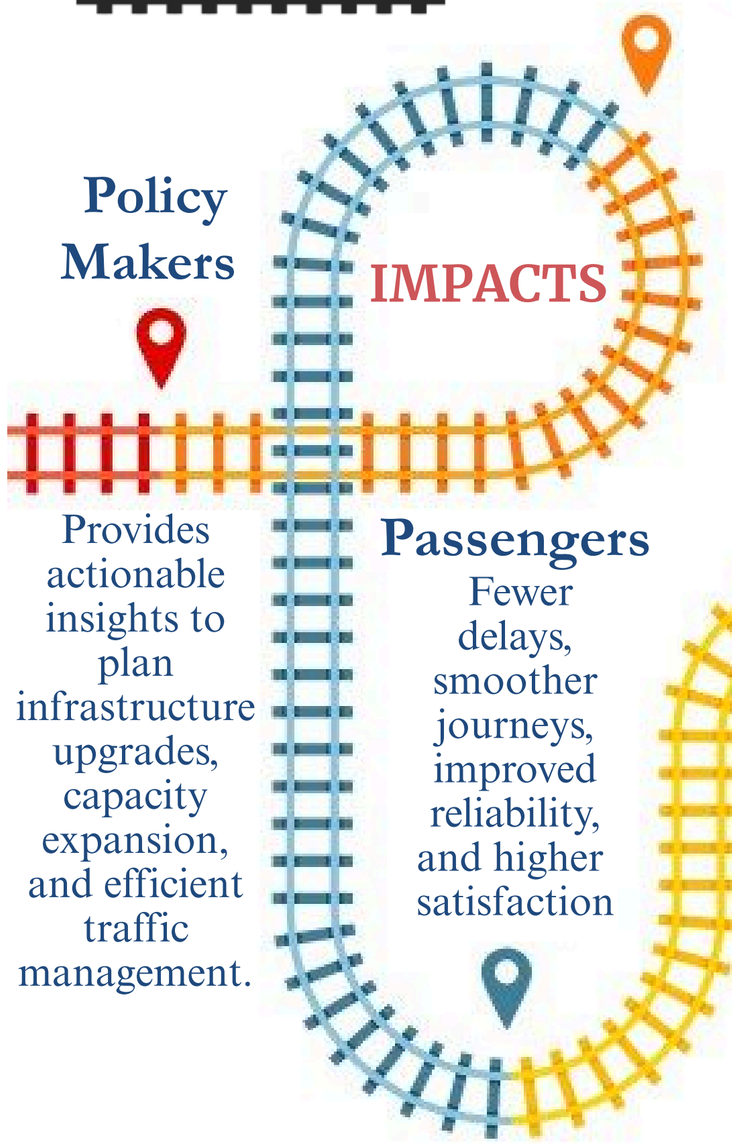

Section Controller

Automates complex scheduling decisions, reduces cognitive load, and empowers faster, safer choices.

Policy Makers

Provides actionable insights to plan infrastructure upgrades, capacity expansion, and efficient traffic management.

Passengers

Fewer delays, smoother journeys, improved reliability, and higher satisfaction

Railway Operators

Maximizes network throughput, optimizes platform and track utilization, and reduces operational bottlenecks.

BENEFITS

Intuitive Decision Support

Interactive dashboards, maps, charts, and reports make insights immediately actionable

Operational Excellence

Real-time AI-driven train scheduling ensures punctuality and safety across high-density networks.

Predictive & Proactive

Forecasts delays, suggests rerouting, and enables rapid scenario simulations for disruptions.

Economic Efficiency

Minimizes delays, reduces fuel and energy consumption, and lowers operational costs

RESEARCH AND REFERENCES

Research & References

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- https://www.sciencedirect.com/science/article/abs/pii/S0305054821001842
- https://www.sciencedirect.com/science/article/abs/pii/S0305054821001842

source code repo link

Demo Link

Future Scope/ Scalability

Multimodal Integration → Optimize not just rail, but also freight, metro, and intercity connections for a unified transport ecosystem.

Adaptive Learning Engine → ML models continuously improve from real-time and historical traffic data.

Nationwide Scalability → Extend from individual sections to cover all railway zones and corridors across India, including dense freight + passenger mixes.ud.

Cloud + Edge Hybrid Deployment → Scalable architecture ensures real-time performance at the edge while keeping nationwide coordination in the cloud.

AI-Powered Policy Simulation → Simulate "what-if" strategies (e.g., new express corridors, timetable shifts) before implementation.