SMART INDIA HACKATHON 2025

TITLE PAGE

Problem Statement ID - 25022

Problem Statement - Maximizing Section Throughput Using AI-Powered Precise Train Traffic Control

Theme - Transportation & Logistics

PS Category - Software

Team ID - 64090

Team Name (Registered on portal) - Routix

ROUTIX: AI-POWERED TRAFFIC CONTROL FOR SECTION THROUGHPUT OPTIMIZATION

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THE PROBLEMS

Human Dependency: Train routing relies on station **controller experience**, risking further delays.
Network Overload: Express, freight, local trains compete on **limited tracks**.
Congestion: Limited tracks lead to frequent **delays** and routing **conflicts**.
Outcome: Delays increase, priorities clash, and throughput **stays low** despite demand.

THE SOLUTION

AI-POWERED ENGINE FOR REAL-TIME TRAIN OPTIMIZATION.

- Re-optimizes **schedules live** during delays and disruptions
- Simulates **alternate** halts, **routes**, and platform allocations
- Seamless API **integration** with existing systems
- Resolves **precedence** conflicts using delay-aware logic
- Tracks real-time **KPIs** like delay and section throughput

THE NOVELTY

Unifies disruption handling and throughput maximization.
Section-level rescheduling powered by delay-aware train precedence.
KPI-first simulation: station controllers test changes before deploying live.

LIVE PROTOTYPE (CLICK ON LINK)

www.routix.vercel.app

ROUTIX

TECHNICAL APPROACH

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TECHNICAL STACK

Data Input: Railway Timetables

Core Engine: Python + Gurobi

API Layer: FastAPI + Redis

Data Backend: Supabase

Dashboard: React JS + NexT JS

FastAPI supabase React NEXT.JS GUROBI OPTIMIZATION

OPTIMIZATION ALGORITHM

GNN predicts conflict pairs $\mathcal{C}$ between trains

Objective:
Minimize total penalty:
$\min \sum w_1 \cdot \max(0, h_{\min} - h_{tt'}) + w_2 \cdot \delta_t + w_3 \cdot \mathrm{Idle}_t$

Decision Variables:
$x_{tr} \in \{0,1\}$: Train t assigned to route r
δ_t: Delay for train t
$h_{tt'}$: Headway between t and t'

Tabu Search:
Avoids repeating prior schedules
Guides exploration

Constraints:
(1) $\sum_r x_{tr} = 1$
(2) $h_{tt'} \geq h_{\min}$ for $(t,t') \in \mathcal{C}$
(3) $0 \leq \delta_t \leq \delta_{\max}$
(4) $\mathrm{Idle}_t = \mathrm{Avail}_t - \mathrm{Use}_t$

Optimal routing + delay decisions with minimized conflict and delay cost

Optimization Algorithm: Hybrid GNN + Tabu Formulation

CONTROLLER OPERATIONS FLOW

1. **LIVE SECTION DASHBOARD** — SECTION CONTROLLER
2. **DYNAMIC DETECTION OF DISRUPTIONS**
3. **REAL-TIME OPTIMIZATION & REALLOCATION**
4. **CONTROLLER OVERRIDE + AUTO IMPLEMENTATION**
5. **KPI LOGGING + AUDIT TRAIL**

Login & **Monitor** Operations

Disruptions Detected & Flagged

Optimized **Rerouting** in Real Time

Decision **Review** & Approval

Performance Insights

Architecture built for modular integration with Indian Railways APIs and systems (TMS, signaling, etc.)

FEASIBILITY AND VIABILITY

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FEASIBILITY FACTORS

01 TRAIN DATA ALREADY EXISTS VIA TMS, KAVACH, AND IR APIS — EASY INTEGRATION.

02 REAL-TIME COMPUTATION IS PRACTICAL WITH SCALABLE CLOUD-BASED DEPLOYMENT.

03 OPTIMIZATION METHODS ARE MATURE, USING OR TOOLS, HEURISTICS, AND SIMULATIONS.

04 MODERN DASHBOARDS OFFER INTUITIVE UI USING REACT — ENSURING EASE OF USE FOR TRAFFIC CONTROLLERS.

NON-RECURRING ENGINEERING (NRE) COST

Core Software Development: ₹3L
Optimization, Simulation, and Planning: ₹1L
Testing and Documentation: ₹48K
Overheads & Support: ₹72K
Total Estimated NRE Cost: ₹5.2L

Software	3,00,000
Simulation	1,00,000
Testing	48,000
Support	72,000

CHALLENGES AHEAD & MITIGATION STRATEGY

PAINPOINT	RESOLUTION
MANUAL OVERLOAD	SMART SCHEDULING ENGINE AUTOMATES CONFLICT RESOLUTION
DISRUPTIONS (WEATHER, BREAKDOWNS)	MINIMIZED CASCADING DELAYS.
LACK OF KPIS	DELAY TRENDS, THROUGHPUT TRACKED VIA LIVE DASHBOARDS.
NO SIMULATION TOOLS	CONTROLLERS TEST DECISIONS BEFORE ACTING.

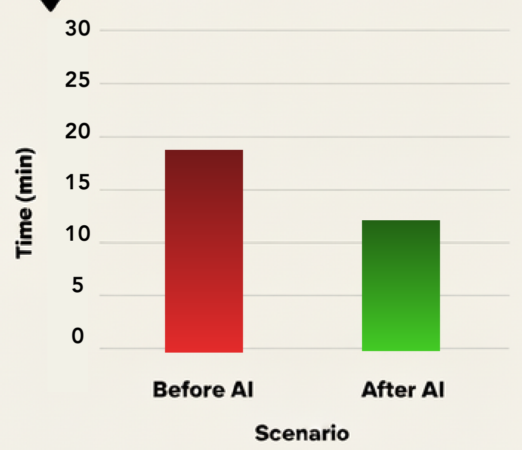
FUTURE SCALABILITY

Nationwide Integration → From sections → zones → entire **Indian Railways**.
Smarter Over Time → AI **learns** from disruptions & seasonal patterns.
Cross-Domain Use → Extendable to metros, freight, **multimodal hubs**.

IMPACT AND BENEFITS

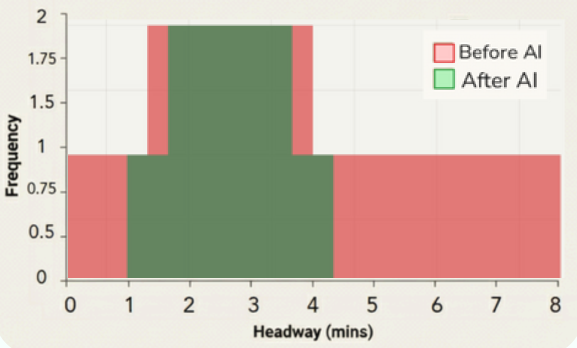
IMPACT QUANTIFIERS

Turn Around Time: ↓ 29.3%

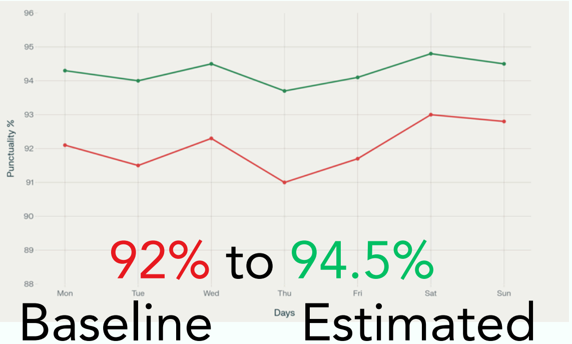


Platform Dwell Time ↓ 6.7%

Service headway adherrance ↓ upto 35.7%



Peak Hour Punctuality



92% to 94.5%

Baseline Estimated

*Data based on simulations and estimations for Mumbai Suburban Railways

SECTION THROUGHPUT

Section throughput is determined through key operational metrics —

- **service headway adherence**
- **peak-hour punctuality**
- **platform dwell time**
- **turnaround time**

— which collectively define network efficiency and capacity utilization.

STAKEHOLDER BENEFITS

GOVERNMENT - Aligns with **Digital Railways** 2030.

RAILWAYS - Higher **throughput**, efficient asset use.

SECTION CONTROLLERS - **Reduced** manual load, override capability retained.

PASSENGERS - Improved **punctuality**, fewer long delays.

RESEARCH AND REFERENCES

ROUTIX

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REFERENCE PAPERS & ARTICLES

Artificial Intelligence Applied on Traffic Planning and Management for Rail Transport: A Review and Perspective. Zhang Jiamin & Zhang Jiarui. (2023). Artificial Intelligence Applied on Traffic Planning and Management for Rail Transport: A Review and Perspective. Hindawi Mobile Information Systems. **https://doi.org/10.1155/2023/1832501**

A literature review of Artificial Intelligence applications in Rail Traffic Planning. Pozna, C., & Dragos, C. (2022). A literature review of Artificial Intelligence applications in Rail Traffic Planning. Transportation Research Part C: Emerging Technologies, 140, 103679. **https://doi.org/10.1016/j.trc.2022.103679**

Optimising a Real-time Scheduler for Indian Railway Lines by Policy Search. Prasad, R., Khadilkar, H., & Kalyanakrishnan, S. (2021). Optimising a Real-time Scheduler for Indian Railway Lines by Policy Search. **Proceedings of ICC 2021, IIT Bombay**.

Trains scheduling problem with multiple lines. Suresh, C.V., & Suresh, N. (2024). Trains scheduling problem with multiple lines. Scientific Reports, 14, Article 82499. **https://doi.org/10.1038/s41598-024-82499-0**

Operations Research for Freight Train Routing and Scheduling. Cordeau, J.-F., Toth, P. (2008). Operations Research for Freight Train Routing and Scheduling. In: Encyclopedia of Operations Research and Management Science. Wiley. **https://doi.org/10.1002/9780470400531.eorms1014**

Dash, Jatindra; V, Abinaya (3 June 2023). "At least 291 dead in India's worst train accident in over two decades". **Reuters**. Archived from the original on 3 June 2023. Retrieved 3 June2023.

"Signal failure led to India's deadly train crash, officials say". **CBC**. 4 June 2023. Archived from the original on 4 June 2023. Retrieved 4 June 2023.

CASE STUDY ANALYSIS ODISHA 2023

Odisha 2023 — wrong-route due to interlocking error
Cause: Maintenance misconfiguration gave a false clear; express diverted onto occupied loop; triple collision.

What Went Wrong:
Signaling System Error: Manual changes caused a false green signal on the main line.
Undetected Anomaly: No AI or automated diagnostics flagged the track-signal mismatch.
Human Oversight: Crew relied on system outputs; protocols lacked fail-safes.
No Real-Time Protection: Absence of automated train protection prevented forced stoppage or rerouting.

How could it have been averted: **Post-maintenance** validation enforced; movement authority denied on mismatch; **no wrong-route clearances** in repeats.