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- **TITLE PAGE**
- **Problem Statement ID – SIH25022**
- **Problem Statement Title-** Maximizing Section Throughput Using AI-Powered Precise Train Traffic Control
- **Theme-**Transportation & Logistics
- **PS Category- Software**
- **Team ID-**
- **Team Name - CODEX**

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IDEA TITLE

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AI-Powered Precise Train Traffic Control

IDEA / SOLUTION

Implementation of an **AI-Powered Train Traffic Control Decision Support System (DSS)** to maximize section throughput and minimize delays by combining **real-time digital twin + AI/ML optimization**.

- Real-time **network digital twin** for monitoring trains, signals, and tracks.
- **AI/ML-based prediction** for delays, disruptions, and conflicts.
- **Optimization engine** (OR + Reinforcement Learning) for re-scheduling.
- **Controller dashboard** with decision recommendations & simulations.
- Seamless integration with **TMS, signaling systems, and Kavach**.

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Problem Resolution

- Current manual precedence causes **delays, congestion, and inefficiency**.
- Lack of predictive control leads to **cascading delays across sections**.
- AI DSS provides **real-time conflict resolution, efficient rescheduling**, and ensures **safety with punctuality**.

Unique Value Propositions

- **Maximized section throughput** with intelligent scheduling.
- **Real-time rescheduling** within seconds during disruptions.
- **Works efficiently in varied operational conditions** (high-density + low-resource routes).
- **Quad-layer safety integration** with signaling & Kavach.
- **Optimized asset utilization** → higher efficiency without extra infrastructure.

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TECHNICAL APPROACH

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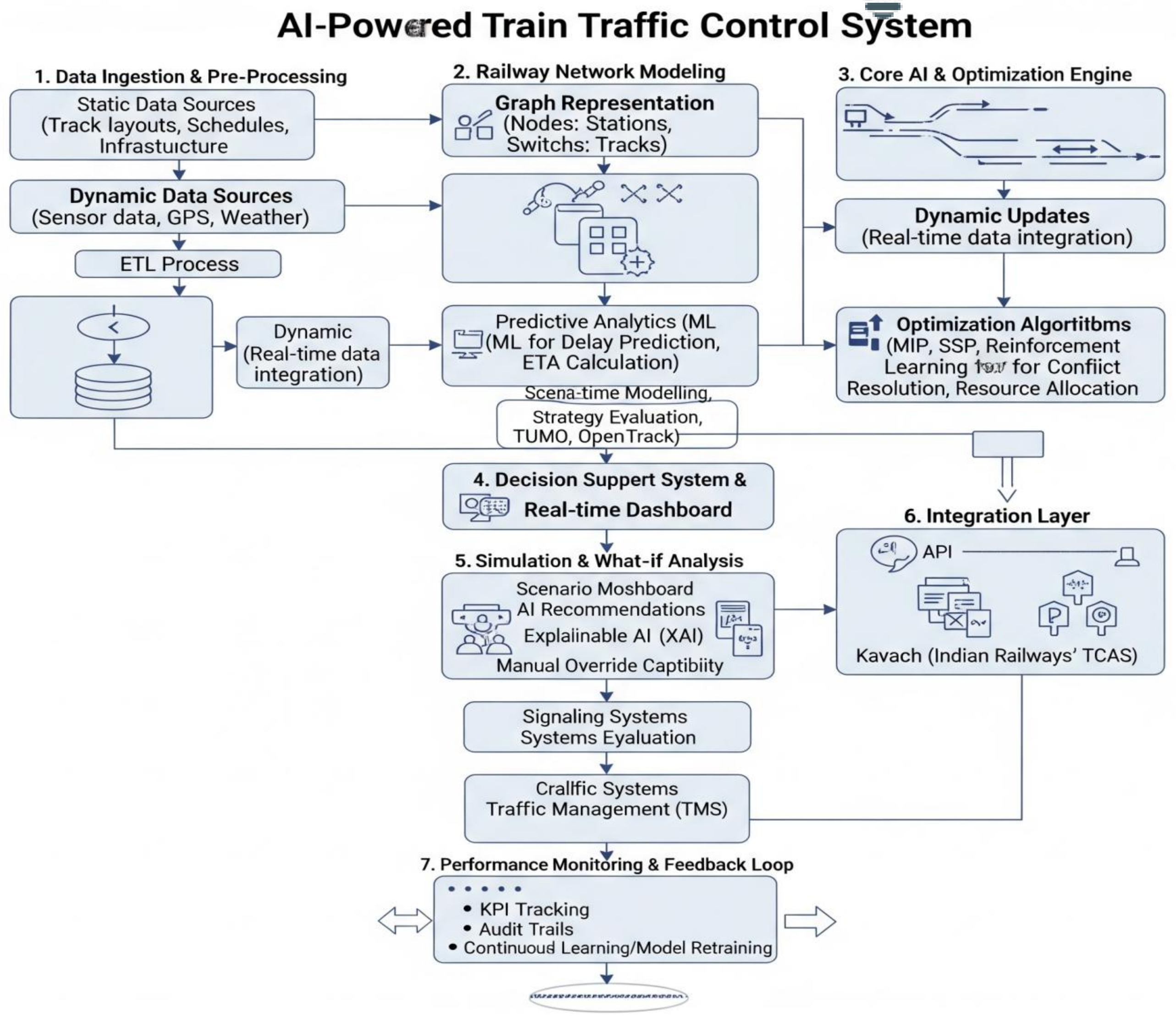
Data Ingestion & Modeling: ETL pipeline integrates static (schedules, track geometry) and dynamic (RTIS, signal status) data to build a graph-based digital twin.

AI & Optimization Engine: Combines ML for predictive analytics (delays, ETA) with optimization (MIP, RL) for real-time, conflict-free scheduling and resource allocation.

Simulation & What-If Analysis: Uses SUMO/Open Track to validate scenarios and control strategies before implementation.

Decision Support Interface: Real-time dashboard with XAI-driven recommendations and manual override for controllers.

Integration & Monitoring: Secure API integration with Signaling, TMS, Kavach, plus KPI tracking, audit trails, and continuous learning for improvement.



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FEASIBILITY AND VIABILITY

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FEASIBILITY AND VIABILITY

Technical: Uses proven tools (ETL pipelines, ML libraries, OR-Tools, simulators); RTIS + signaling data already available.

Operational: Designed as a DSS with manual override; can be integrated smoothly via phased rollout.

Financial: High initial cost, but ROI through delay reduction, throughput gains, and optimized rolling stock.

Market: Validated by Ministry of Railways; scalable from section-level to national network

1

2

3

POTENTIAL CHALLENGES AND RISKS

Technical: Legacy system integration, ensuring real-time reliability, fail-safe operations.

Operational: Resistance to change, cultural shift, SOP and training updates required.

Financial: High upfront investment, risk of integration cost overruns.

STRATEGIES FOR OVERCOMING CHALLENGES

Technical: Pilot rollouts, microservices + RailML for interoperability, CSP-based safety checks

Operational: Co-develop with controllers, use Explainable AI (XAI), simulator-based training.

Financial: Build strong business case with measurable KPIs (delay reduction, throughput gains) to justify funding.

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IMPACT AND BENEFITS

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Our Target Audience

Train Traffic Controllers, Passengers & Freight Customers, Ministry of Railways & Policy Makers

1

SOCIAL BENEFITS

- Safer Railway Network through AI-based conflict-free schedules
- Improved commuter quality of life via reliable and punctual travel
- Stronger regional and national connectivity

2

ECONOMIC BENEFITS

- Increased track capacity without heavy infrastructure costs
- Reduced operational costs (fuel, overtime, penalties)
- Boost to logistics efficiency and national competitiveness

3

ENVIRONMENTAL BENEFITS

- Reduced carbon footprint via optimized routing & speed
- Lower fuel consumption and minimized idle time
- Encourages shift from road to eco-friendly rail transport

4

KEY BENEFITS

- Reliable, safe, and efficient railway operations
- Economic empowerment through efficient logistics
- Contribution to India’s sustainability and green goals

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RESEARCH AND REFERENCES

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ACADEMIC PAPERS

Foundations in Reinforcement Learning, GNNs, MIP optimization, CSPs (Šipr & Hanzálek, 2022; Zhan et al., 2021; Lamorgese & Mannino, 2020)

Indian Railways Vision 2030 – Government roadmap for modernization and smart technologies in railways. https://indianrailways.gov.in/railwayboard/uploads/directorate/infra/

OFFICIAL PUBLICATIONS

Indian Railways General Rules (1976), Kavach Safety System, CRIS RTIS documentation.

AI Applications in Railway Transport – A review of how AI is already used in railways worldwide. https://www.sciencedirect.com/science/article/pii/S0968090X22001206

Digitalization of Railway Transportation using AI and Digital Twins (2024) – Explains how AI and IoT improve train operations and passenger experience. https://etrr.springeropen.com/articles/10.1186/s12544-024-00679-5

TECHNICAL REFERENCES

APIs & optimization tools (Google OR-Tools, Pravah API Gateway, OpenTrack, SUMO).

CASE STUDIES

Hitachi & JR East AI dispatching, ERTMS (EU).

COMMUNITY SOURCES

IRFCA FAQs, India Rail Info (practical signaling & timetable insights).