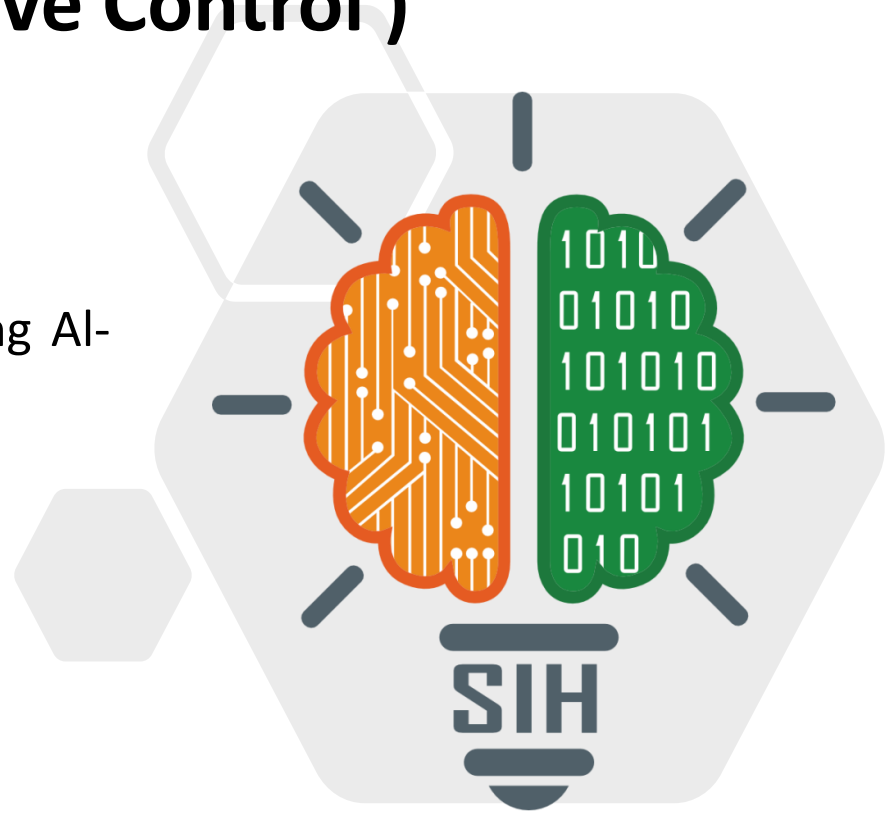
SMART INDIA HACKATHON 2025

Project MargDarshak

(A Digital Twin-Driven Adaptive Control)



- **Problem Statement ID –** 25022
- **Problem Statement Title -** Maximizing Section Throughput Using AI-Powered Precise Train Traffic Control
- **Theme -** Transportation & Logistics
- **PS Category-** Software
- **Team ID - 99427**
- **Team Name -** Team_NoGPT

Team No_Gpt

❖Digital Twin-Driven Adaptive Control

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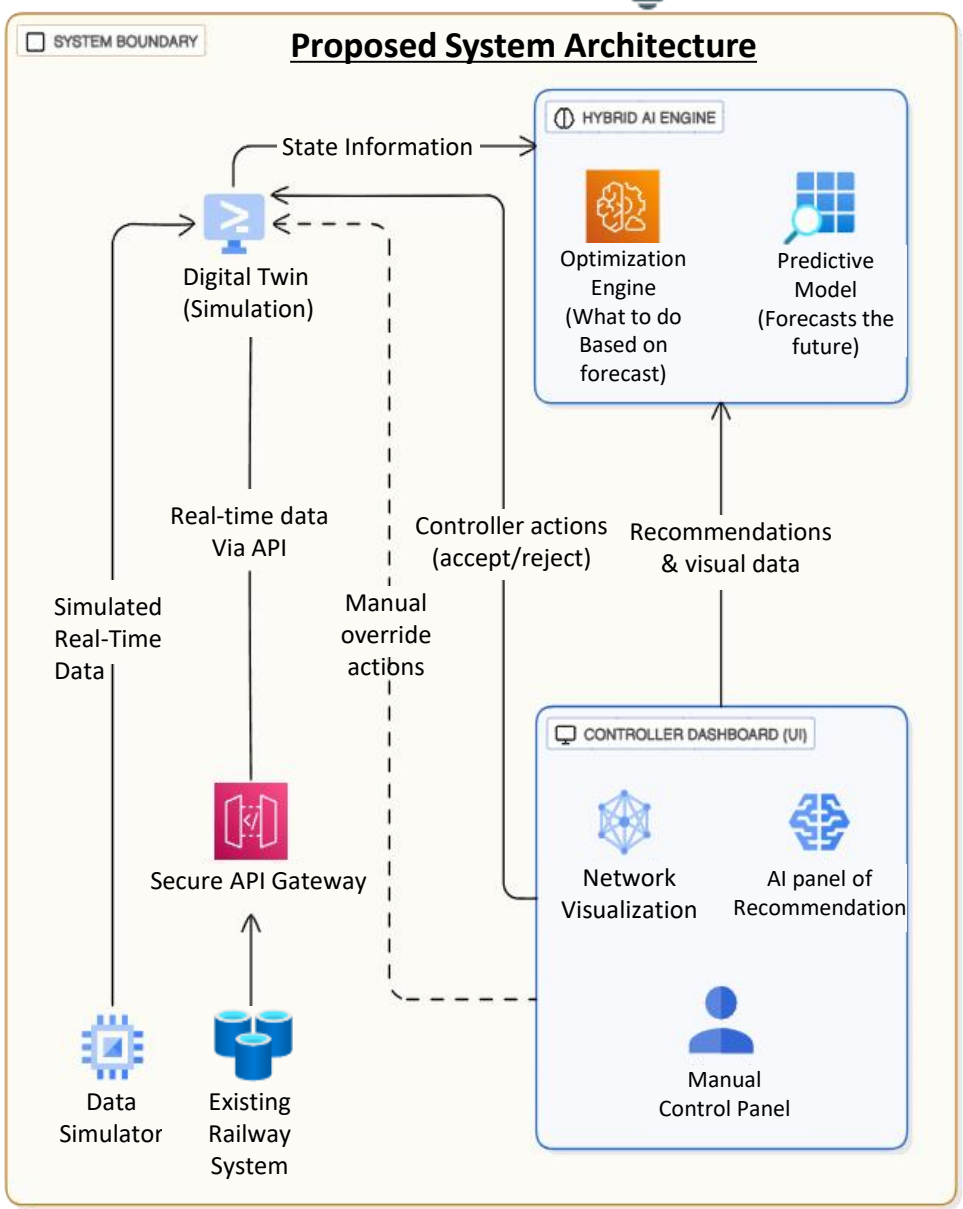
Proposed Solution Explanation	How it Addresses the Problem
1. **Decision-Support Tool** – a system that helps users make informed choices by analyzing data and presenting actionable insights 2. **Digital twin: a virtual model of a real-world object, system, or process**, used to monitor, simulate, and improve its performance. 3. **Core Components** – Data Simulator, Digital Twin (train/test), AI Engine, and Controller Dashboard (UI). 4. **Hybrid AI Engine** – Uses XGBoost for ETAs & delay impacts, combined with RL Optimization for best actions. 5. **Why this Approach?** – It offers a safe, risk-free way to handle complex scenarios; AI proposes plans while human controllers retain final authority.	▪ **Automates Optimization (What):** Solves real-time precedence scheduling (a complex combinatorial challenge). ▪ **Maximizes Efficiency (Why):** Improves throughput and reduces overall delays, addressing the growing congestion problem. ▪ **Handles Disruptions (When):** Quickly re-optimizes during unforeseen events like breakdowns, incidents, or weather delays. ▪ **Reduces Human Error (Who):** Assists controllers by providing reliable, data-driven recommendations under pressure. ▪ **Provides Predictive Insight (Where/What-if):** Simulates future scenarios using the Digital Twin to test strategies before applying them.
	Innovation & Uniqueness
	Predictive Optimization: Combines forecasting + optimization, unlike static systems. **RL Core:** Learns adaptive strategies from experience, not fixed rules. **Digital Twin:** Safe, realistic training/testing before deployment. **Decision Support, Not Replacement:** Keeps human authority while enhancing capabilities.

Proposed System Architecture



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TECHNICAL APPROACH

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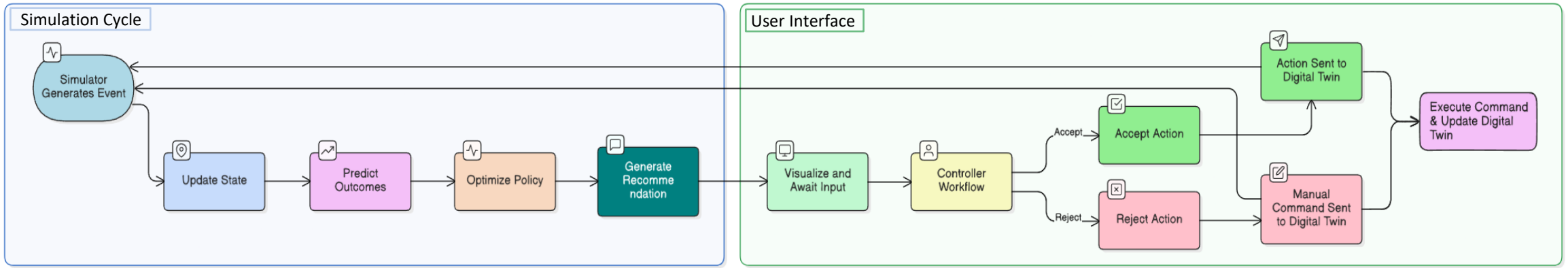
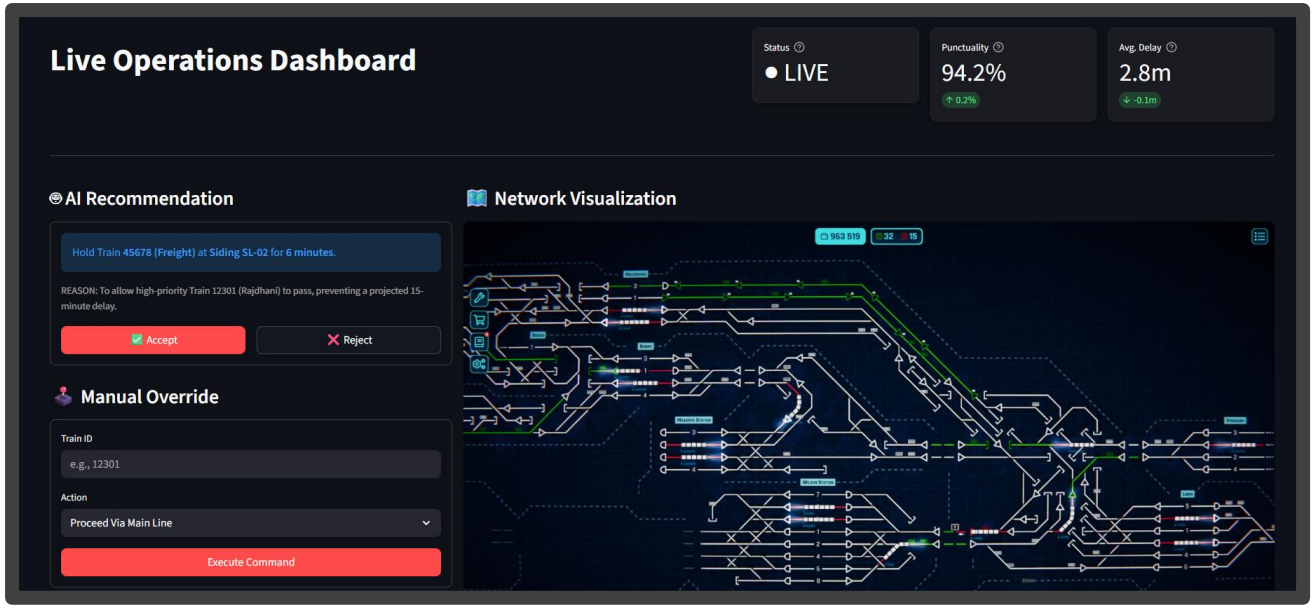
Methodology & Work Flow:



Technology Stack

Backend & API: Python, Flask (REST API)
AI & ML: TensorFlow/PyTorch (RL), Scikit-learn/XGBoost (ETAs), OpenAI Gym/Gymnasium (simulation), MLflow (experiment tracking)
Simulation: SimPy (discrete-event), Custom Python classes (trains, tracks)
Data & DB: Pandas, NumPy, SQLite (prototype), PostgreSQL (production)
Frontend: Streamlit (dashboard), Plotly/Matplotlib (visualization)
Deployment & Cloud: Docker (containerization), AWS/GCP/Azure
Security: HTTPS (SSL/TLS), Environment variables (secrets), Input validation (API/UI).



Prototype (Controller Dashboard)

(Click on the image to visit the working Prototype)

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FEASIBILITY AND VIABILITY

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Simulator Use

Custom simulator enables development without live railway data.

Open-Source Tech

Open-source tools ensure accessibility & low development costs.

Decision Support System

System enhances human controllers, not replaces them.

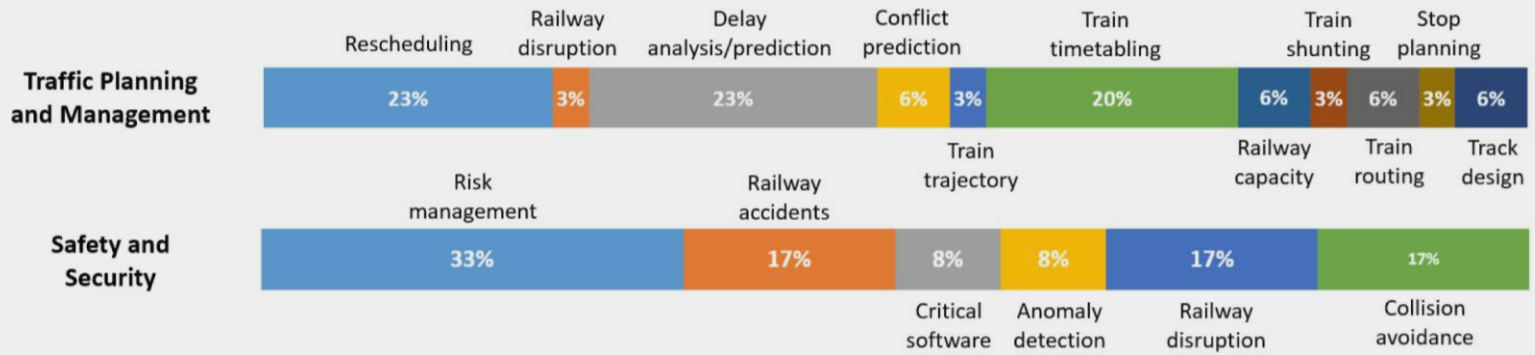
Economic Benefits

Project offers significant economic benefits and high ROI.

High Potential

Increases capacity, reduces delays, saves fuel

Feasibility



Project Focus based on research and requirements

	User Resistance	Proving System Value	Workflow Distribution	Training Overhead
Challenges & Risks	Controllers may distrust AI, fearing loss of control.	Hard to integrate with legacy systems; changes may disrupt routines.	Users may hesitate without tangible benefits.	Complex system may slow adoption.
Mitigations	Human-in-the-loop design; AI suggests, humans decide.	Modular architecture + intuitive dashboard; enhances workflows without replacing them.	"What-if" simulations + KPIs (throughput, delays) to show impact.	Simple, user-friendly dashboard with clear visuals for quick learning.

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IMPACT AND BENEFITS

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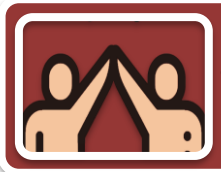
Operational Revolution: From reactive to predictive control—AI-driven railways placing **India** ahead **globally**.

Better Decisions: Optimizes choices beyond intuition.

Reduced Load: Clear, actionable suggestions ease pressure in congested traffic.

Decision Support, not Replacement: Assists controllers with data-driven strategies while preserving their authority.



Safety & Proactive Control: "What-if" simulations enable planning ahead

Impact on Section Controllers

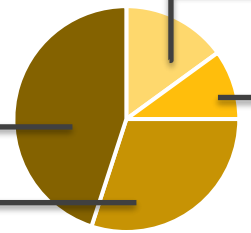
Economic

- High ROI in IRL deployment.
- Optimized schedules increase track capacity, delaying costly expansions.
- Maximizes throughput (more trains per section per hour).

Environmental

- Less idling → lower fuel use & emissions.
- Future scope for energy-aware scheduling (optimize power consumption).

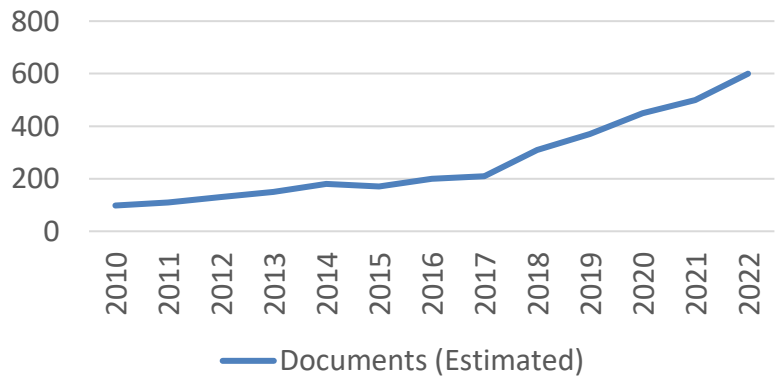
Contribution



Social

- Improved punctuality boosts customer satisfaction.
- Reduced travel times benefit passengers and freight alike.

AI **Research** Trend in Railways



RESEARCH & REFERENCES

- **Our Project work progress and demo videos: https://github.com/Yathivarun/SIH-Section-Throughput-of-Railway**
- **Link to working prototype of design : https://sih-section-throughput-of-railway-sjthgarpfng33blzrzlrdz.streamlit.app/**
- **AI for Railway Optimization:** We draw from research on MILP-based algorithms and Reinforcement Learning (RL) for real-time train dispatching and scheduling, ensuring our core model is robust and effective. *(Refs: Aradi, S. 2023; Li, et al. 2020; DiVA portal, 2023)*
- **Smart Traffic Management Systems:** Our approach incorporates principles from modern AI-driven traffic control and rail signaling technologies to create a feasible and integrated system. *(Refs: IJFMR, 2024; Thales Group; ResearchGate)*
- **Economic & Social Impact Analysis:** The project's value proposition is validated by studies on the high economic cost of rail disruptions and the significant ROI from logistics and infrastructure investments. *(Refs: AAR.org; World Bank, 2025)*
- **RailTwin (UAE, Univ. of Ottawa & MBZUAI):** A digital twin framework combining prediction and decision-making for railway operations.
- **Greater Anglia + Toshiba (UK):** AI-powered digital twin system for real-time train timetabling and optimization.