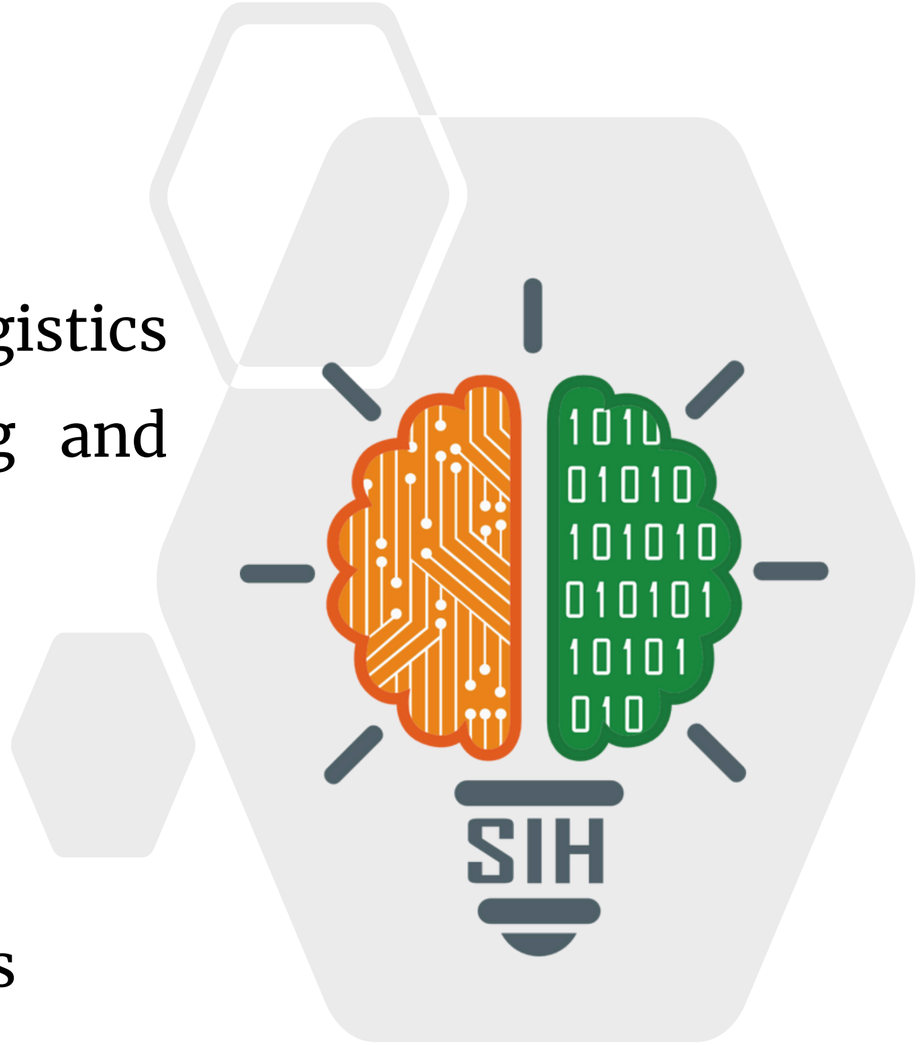
SMART INDIA HACKATHON 2025

TITLE PAGE

- **Problem Statement ID –** 25209
- **Problem Statement Title –** Al-Enabled Logistics Optimizer for Cost-Optimal Vessel Scheduling and Port-Plant Linkage in Steel Supply Chain
- **Theme –** Transportation & Logistics
- **PS Category –** Software
- **Team ID –** 102098
- **Team Name (Registered on portal) –** RailOptimus



IDEA TITLE

Idea/Solution

- An **AI-powered decision**- support module for **vessel scheduling** and port–plant dispatch, **optimizing** end-to-end sea-to-rail **logistics**.
- Uses **mixed-integer linear programming and heuristics** to generate least-cost, constraint-feasible plans (port calls, rail rakes, stock capacities, quality blends).
- Integrates a **predictive AI engine** to estimate pre-berthing and turnaround delays at load/discharge ports; feeds demurrage and ETA into optimization.
- Incorporates **dynamic stock arrivals** linked to **vessel ETA and semi-discrete cargo parcels**; models time/step-dependent port and rail costs.
- Provides interactive **what-if simulations** to test **alternate ports, vessel sequences, rake availability**, and **dispatch priorities.**
- **Dashboard-centric approach:** live vessel/stock views, KPIs, cost breakdowns, and map-based port–plant flows via a responsive web UI.
- **Modular architecture with data adapters** for SAP/Excel and REST APIs, enabling production integration and future ML extensions.

Problem Resolution

- **Replaces spreadsheet-heavy**, intuition-led planning with consistent, data-driven **least-cost schedules**.
- **Resolves conflicts** across port capacities, rake limits, plant stock constraints, and max port calls while **honoring sequential discharge rules (e.g., Haldia second).**
- **Prevents demurrage and stockouts** by aligning vessel ETA, berthing predictions, and dispatch timing to plant demand and quality requirements.

Unique Value Preposition

- **AI Predictor**
  Port pre-berthing/turnaround forecasts directly drive demurrage and ETA-aware plans.
- **Interactive Map & Simulation**
  Visual exploration + rapid scenario testing.
- **Optimization Core**
  MILP + heuristics produce transparent, explainable cost-optimal dispatch and port-call schedules.
- **Polished UX**
  Clean, responsive UI with maps, charts, and role-based views; supports quick re-optimization on live updates.
- **Data-First Integration**
  Pluggable connectors for SAP/Excel and REST services; no UI changes needed when swapping data backends.

TECHNICAL APPROACH

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shadcn/ui

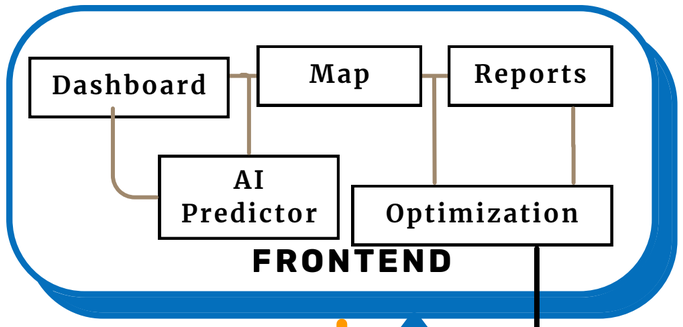
Leaflet

cors

React Router

Toastify

MERN



BACKEND

REST APIs' & FLASK APIs'
routes, vessels, users

NodeJS + Express

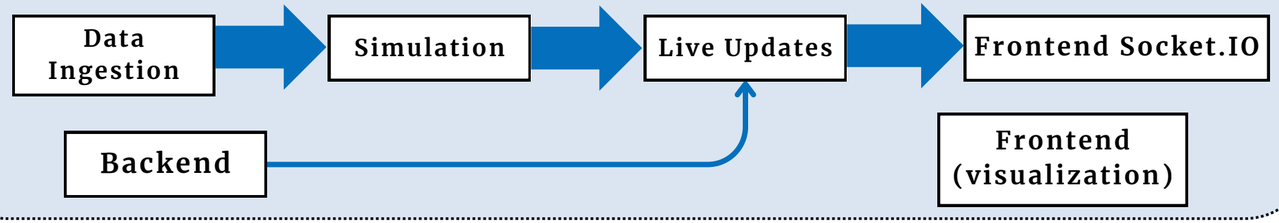
Socket.IO

MongoDB

ML

Python-based delay prediction
- Vessel Delays
- Berthing Delays
- Freight Delays

DATA FLOW



Initialization & Planning

Initialize System
- Build port–plant network graph
- Create vessels and cargo parcels
- Setup demurrage prediction model (AI/ML)
- Load input data (STEM, stock, rake, costs, constraints)

MILP Optimization

For each vessel–port–plant combination, compute least-cost allocation under:
- Port & plant capacity limits
- Quality-specific demand
- Sequential discharge constrain
- Rake & rail availability
- Ocean freight, handling, demurrage

Not Arrived → check vessel ETA & port availability →enter port queue or wait offshore

- Sort arriving vessels by ETA and cost priority
- Increment current time slot
- Update stock arrivals & vessel positions

Simulation and optimization

Berth availability
Vessel arrivals (update ETA)
Berth delays (apply demurrage)

Running?

Follow plan, handle:
- Port congestion (wait offshore)
- Berth unavailability (wait)
- Stock overflow at port (delay dispatch)
- Rail unavailability

At Port → unload cargo → update port stock → dispatch to plant

Update & Advance

End

All vessels dispatched and plant demands fulfilled or Maximum time slots reached

FEASIBILITY AND VIABILITY

Feasibility Analysis

Technical:

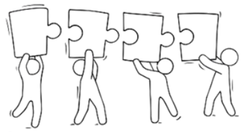
- **Enterprise stack:** React + TypeScript, Node.js + Express (APIs), Python (MILP/heuristics).
- **Optimization core**: MILP + heuristics with pluggable solvers for time-dependent costs, semi-discrete parcels, and integer rakes.
- **Event-driven re-optimization** via API/webhook/WebSocket on ETA, berthing, and rake updates.
- **AI delay prediction** (Python) for pre-berthing/turnaround; demurrage-aware schedules looped into MILP.
- **Data adapters**: **SAP** (OData/IDoc) and **Excel** (CSV via data_loader.py) for secure, incremental integration.
- **Microservices architecture**: optimization, data, and UI services with independent scaling and CI/CD.

Financial:

- **Open-source-first** stack reduces licensing costs; commercial solver optional for performance when ROI is proven.
- **Leverages existing SAP, port, and rail IT**—minimal new CAPEX; cloud/hybrid-ready deployment.
- **Automation** reduces demurrage, avoidable rail costs, and stockout buffers—clear payback via saved penalties and better rake utilization.

Market / Operational:

- **Planner-friendly workflows**: scenario runs, port-call edits, and dispatch overrides mirrored in the UI.
- **Throughput gains** via ETA-aware vessel sequencing and rail rake alignment under capacity constraints.
- **What-if scenario simulator** for port choice, Haldia-sequence enforcement, and max-port-call policies; supports planning.
- **High adoption potential with tangible KPIs** (cost/ton, demurrage hours, service level); audit logs and reports for governance.



Challenges

- **Technical:** Multi-commodity MILP with time-bucketed inventories, sequential discharge (e.g., Haldia second), max port calls, and dynamic ETAs at scale.

- **Financial:** Potential solver licensing and ongoing ML ops costs across multiple plants/ports.

- **Operational / Market:** Data quality from SAP/ports, change management for planners, and coordination with railway rake allocation.

Strategies to overcome

Operational: Intuitive UI with guided flows, sandbox scenario training, role-based access, and secure APIs for SAP/port systems.

Algorithms: ML for pre-berthing/turnaround prediction; MILP with rolling horizon + warm starts; heuristics for fast re-optimization; robust penalties for uncertainty.

Financial: Phased rollout by corridor/plant, cloud-first to reduce infra costs, open-source solver baseline with upgrade path as needed.

Technical: Modular services, event bus for updates, WebSocket/SSE for live dashboards, caching and offline CSV fallback for continuity.

IMPACT AND BENEFITS

IMPACTS

Plant Operations
Ensures timely, quality-compliant arrivals; lowers stockouts and safety buffers through synchronized dispatch and balanced inventories.

Port & Rail Operators
Improves berth planning and rake allocation using ETA and pre-berthing delay predictions; reduces congestion, idle time, and turnaround.

Finance & Policy Makers
Delivers cost transparency (ocean, rail, handling, demurrage), KPI tracking, and insights for capacity planning, contracts, and capital allocation.

Logistics Planners
Automates vessel-port-plant scheduling, reduces cognitive load, and enables faster, constraint-compliant, least-cost decisions with what-if simulations.

BENEFITS

Intuitive Decision Support
Dashboards, maps, cost breakdowns, and reports make port-plant flows and risks immediately actionable.

Operational Excellence
End-to-end sea-to-rail optimization enhances punctuality, capacity utilization, and adherence to constraints (capacities, max port calls, Haldia sequence).

Predictive & Proactive
AI-driven pre-berthing/turnaround forecasts feed ETA-aware plans; rapid re-optimization and disruption simulations for delays.

Economic Efficiency
Minimizes total cost by optimizing ocean freight differentials, port handling/storage, rail freight, and demurrage.

RESEARCH AND REFERENCES

Research & References

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source code repo link

YouTube Demo Link

Future Scope/ Scalability

Multimodal Integration → Optimize coordination between ocean freight, port handling, and rail dispatch for a seamless end-to-end supply chain.

Adaptive Learning Engine → ML models continuously improve using real-time vessel, port congestion, and dispatch performance data.

Nationwide Scalability → Extend from individual ports and plants to a unified multi-port, multi-plant logistics network covering all major coastal and inland corridors across India.

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

AI-Driven Dispatch Simulation → Evaluate alternate port–plant routing, vessel sequencing, and rake allocation strategies for cost and delay optimization.