Case Study-TATA 1mg

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Problem Statement:
Persistent Delays in Indian Railways

Indian Railways is a body under the ownership of the Ministry of Railways of the Government of India that operates India's national railway system. It manages the **fourth largest national railway system** by size with a running track length of 106,493 km (66,172 mi). In 2018–19, it operated **13,523 trains** and **carried 8.44 billion passengers** and transported **1418.1 million tonnes of freight**. Source

Impact of the Delay of Trains in India

Source

Freight Revenue Losses:



- Freight operations form the backbone of Indian Railways, generating **70% of its revenue**, but delays create a **domino effect** on supply chains.
- Annual freight losses due to delays are estimated at a **staggering ₹10,000 crores**, affecting industries like coal, cement, etc.

Passenger Disruptions:



- Every day, **over 25 million passengers** rely on Indian Railways, and delays severely disrupt their schedules, causing lost productivity, and stress.
- During the peak fog season, especially in northern India, **70% of passenger trains** are delayed.

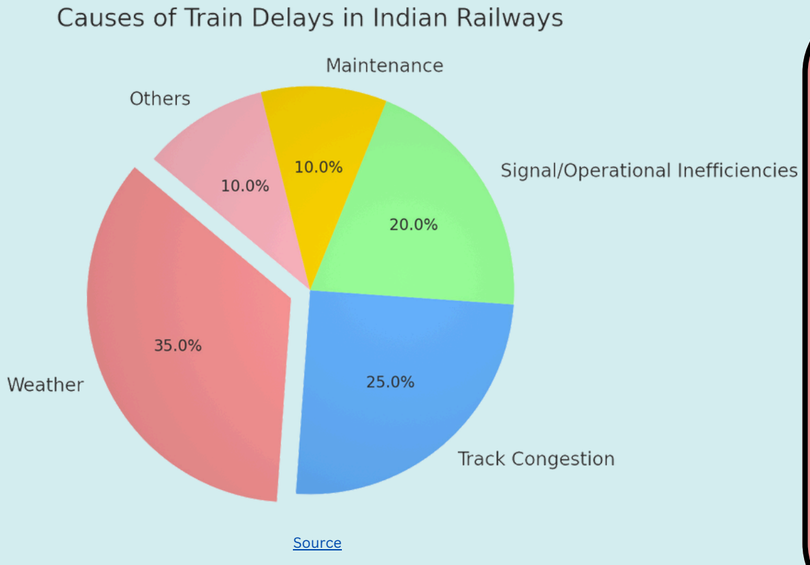
Economic and Operational Costs:



- The railways contribute ~2% to India's GDP, but delays **hinder efficiency and reduce their economic value**.
- Unnecessary fuel consumption from frequent stops and slowdowns increases **operating costs** in the form of fuel cost.

Key Issues and Prioritization

Key Problems to be Addressed for Train Delays



Source

Weather

- Adverse weather conditions such as fog, heavy rains, and **low visibility** significantly hinder train punctuality.
- Dense fog in northern India during winters reduces visibility to **less than 50 meters**, leading to slower speeds and increased delays.

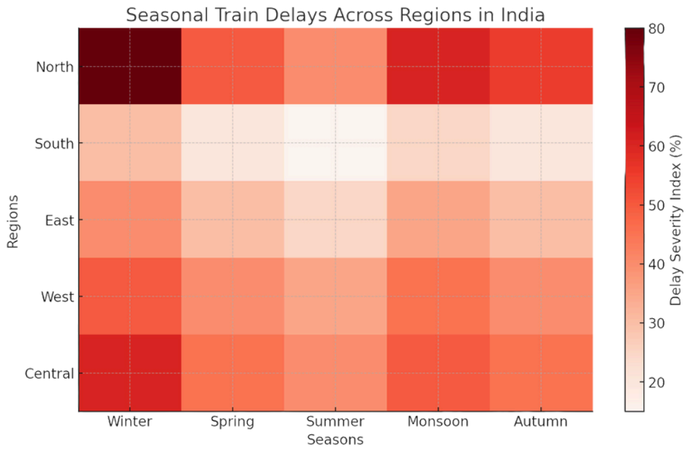
Track Congestion

- **Poor optimization** of available tracks leads to congestion and **compounded delays**.
- Lack of **real-time data integration** limits the ability to dynamically adjust train routes.

Operational Inefficiency

- Current reliance on manual systems for **monitoring, signalling, and managing** train schedules have a lot of inefficiencies.
- With the current systems in place, **to ensure safety**, we cannot do a significant optimization.

The Ripple Effect of Delays: One delayed train doesn't just stop there—it causes congestion on tracks, delaying other trains leading to a **chain reaction of inefficiencies**.



Breaking down the Weather problem:

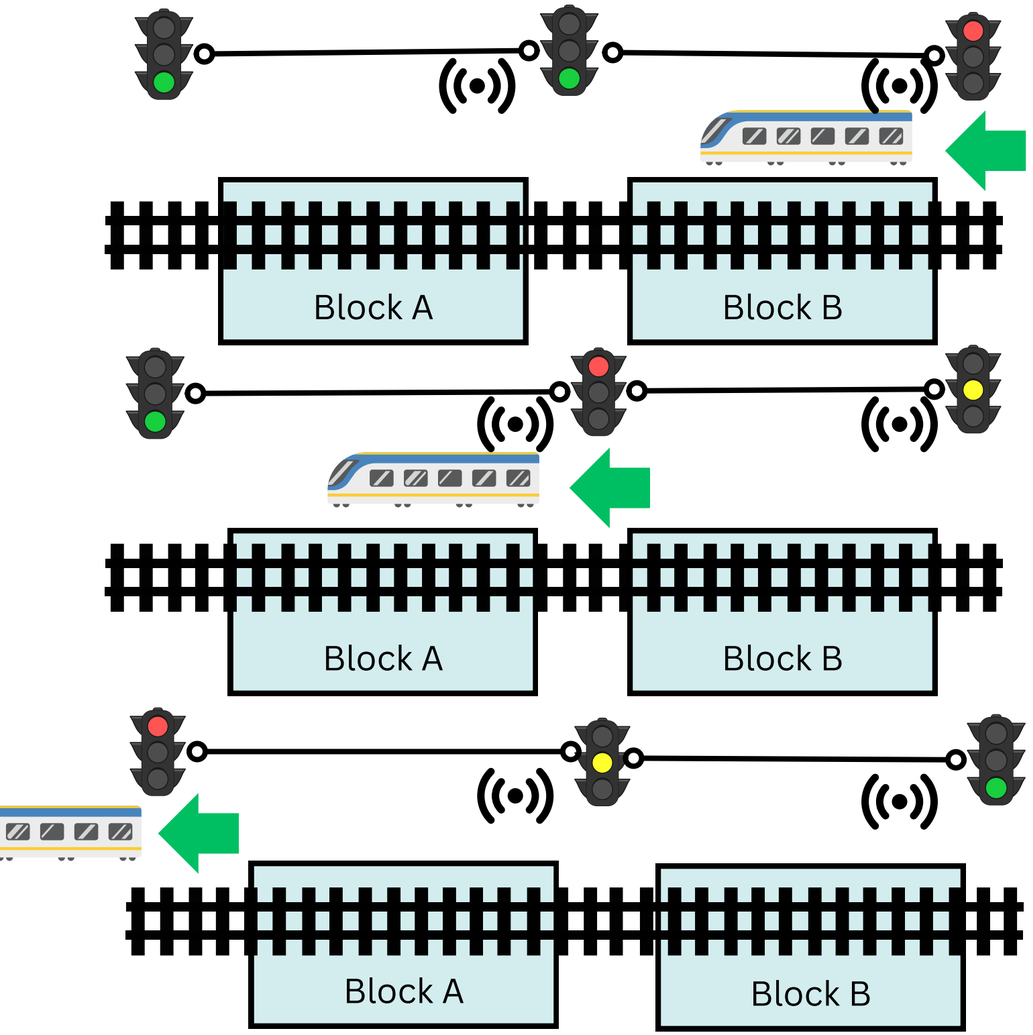
- Current signal systems rely on visual indicators, which are **ineffective in low-visibility conditions.**
- Drivers must **slow trains down to ensure safety**, increasing travel time and congestion.
- Trains operating at slower speeds in fog often disrupt schedules across multiple routes.
- Each delayed train occupies critical track space longer, preventing timely movement of others.



Dense fog in northern India during winter reduces visibility , forcing trains to slow down

Understanding Current System of Automatic Block Signalling

As of March 2023, around 3,549 km of the route uses **automatic block signalling** for train operations – concentrated in high density routes, large cities and junctions. Remaining routes are based on absolute block signalling with trains manually controlled by signal men from the signal boxes typically located at stations. Few low density routes still use manual block signalling methods with communication on track clearance based on physical exchange of tokens. Source



Components of the System

Railway Tracks Divided into Blocks:

- The railway track is **segmented into multiple "blocks"** with each block being a fixed section of track monitored by sensors.
- Each block has entry and exit points controlled by signals.

Track Sensors:

- Installed on each block **to detect the presence of a train**. When a train enters a block, the circuit recognizes its presence by completing or disrupting an electrical signal.

Signal Lights:

- Each block has a signal light indicating its status:
  - Green (Clear): Block is unoccupied; train can proceed.
  - Yellow (Caution): The next block is occupied, so trains should slow down.
  - Red (Stop): Current block is occupied; trains must halt.

Control Systems:

- Automated control units manage the status of each signal **based on the presence of trains in adjacent blocks.**

Working of the System

- When a **train A** passes a traffic light and enters the next block, the track sensors detect the train and signal changes to Red for the previous block, Yellow for the previous to previous block.
- So, when a **train B** is coming behind the **train A,** it is indicated by the signal to stop 1 block before train A and indicated to slow down 2 blocks before train A.
- This system ensures there is no **possibility of collision** between the trains.

Proposed Solution: Real-Time Traffic Light and Speed Guidance System



Train Screen Shows Allowed Speed and Signal Ahead

Computed Data

Centralized system

Real Time Data of Identified Block of Trains

Real Time Data from the Traffic light Sensors

Need of Driver to see the Physical Traffic Light and Act is **Eliminated** → Instead of depending on human visibility, the system uses sensor data → So, any visibility obstructed by fog, rain, etc. will not slow down the train

Major Components of the System

Data Collection from Traffic Lights

- **Sensors installed on traffic lights** continuously monitor their status (Red, Yellow, Green).
- Data from these sensors is transmitted in real-time to a **Centralized Traffic Management System.**

Centralized System with Train Position Data



- **Integrates real-time data** from traffic light sensors.
- An **algorithm** dynamically calculates the maximum safe speed and signal status for every train based on the data.

Driver Cabin Screens for Visual Guidance



- Each train is equipped with a screen in the driver's cabin.
- Displays the status of the next traffic light (e.g., Stop, Slow, Go) and **real-time speed guidance based on current train position, and other trains' locations.**

Execution Plan

1. Pilot Phase (Proof of Concept)



Objective: Test the **feasibility of the system** on a smaller scale before full-scale implementation.

Select a Pilot Region:

- Fog-prone route, such as **Delhi-Amritsar**
- Choose a mix of **passenger and freight trains** for testing.

Run Simulations:

- Conduct **controlled tests** to assess system accuracy.
- Identify technical and operational bottlenecks.

2. Gradual Expansion



Objective: Roll out the system in phases, incorporating **feedback from the pilot phase**.

Phase-Wise Rollout:

- Focus first on regions with frequent delays due to fog or congestion (e.g., Northern Railways during winter).
- Expand gradually to other zones based on priority and impact.

Train Crew Training:

- Develop a **training program** for drivers and railway staff on using the system.

3. Full-Scale Implementation



Objective: Deploy the system across all zones of Indian Railways.

Nationwide Rollout:

- Begin with high-density corridors like Delhi–Mumbai and Delhi–Kolkata, which handle a significant portion of India's passenger and freight traffic.
- Expand to less congested zones after refining the system.

Collaboration with Private Players:

- Partner with technology companies for sensor production, system integration, and maintenance services.

Monitoring and Continuous Improvement

Real-Time Monitoring:
Use a **centralized dashboard** to monitor system performance and potential malfunctions.
Feedback Mechanism:
Collect **feedback** from train drivers and control room staff regularly.



Benefits of the Proposed Solution Over the Old System

Category	Current System	Proposed System
Weather Resilience 	• Physical traffic lights are highly **dependent on visibility**, making them ineffective in fog or bad weather.	• **Eliminates reliance on physical traffic** light visibility by using real-time data and in-cabin displays. • Allows **safe and efficient** operations even in low-visibility conditions.
Safety and Reliability 	• **Limited communication** between trains and the control centre leads to slow responses to emergencies.	• Trains are equipped with **real-time location and speed monitoring**, reducing the risk of collisions.
Cost Optimization 	• Requires significant **human resources** for signalling, monitoring, and managing schedules. • **High costs** due to inefficiencies, delays, and fuel wastage.	• **Automation** reduces dependency on human labour and associated costs. • Optimized speed and track usage **reduce fuel consumption and operating expenses.**
Track Utilization 	• **Inefficient track utilization** due to rigid schedules and lack of real-time monitoring. • Tracks are often underutillized or congested in certain regions.	• Optimized track allocation using real-time data ensures **balanced utilization**. • Reduces bottlenecks in high-traffic areas and minimizes idle time.

Risks and Mitigations

Risk	Mitigation
Inconsistent or Limited Infrastructure 	• **Gradual Infrastructure Upgrades**: Focus on **high-priority routes** first. • **Hybrid Solution**: Use manual signalling alongside the new system in some areas. • **Data Transfe**r: Use **4G/5G networks** for communication in areas without dedicated systems.
High Initial Costs 	• **Government Funding & PPP:** Seek funding through government initiatives and public-private partnerships. • **Phased Implementation**: Roll out in phases, starting with high-impact regions. • **Leverage Existing Infrastructure:** Use existing systems like **GPS** for data collection, minimizing new hardware costs.
Resistance from Railway Staff and Stakeholders 	• **Training Programs**: Conduct comprehensive training to demonstrate system benefits. • **Stakeholder Engagement:** Work with stakeholders (**drivers, unions, government**) through workshops and collaboration. • **Transparency:** Ensure **clear communication** about how the system benefits staff and passengers.

Key Metrics of Success

NORTH STAR METRIC

On-Time Performance (OTP) Improvement

Compare average delay times before and after system implementation.

For Example: Average delay on Amritsar-Delhi Route was **90 Minutes** in the **month of January** before system implementation and it came down to **40 Minutes** after system implementation.

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Directly Measures our Problem i.e. Delays in Indian Railways

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It is Indirectly Impacting other Metrics

Passenger Satisfaction, Cost-Benefit Ratio, Operational Cost

Metric	How to Measure
Reduction in Operational Costs 	Track reductions in **fuel costs, staffing costs, and maintenance costs**.
Train Speed Optimization & Fuel Efficiency 	Measure **average speed of trains** during adverse weather conditions before and after system implementation.
Passenger Satisfaction 	Use **surveys, feedback forms, and social media sentiment analysis**.
Environmental Impact (Fuel Savings & Emissions Reduction) 	Calculate fuel consumption and **emissions** before and after implementation.
System Scalability & Expansion 	Track the **speed and cost of scaling** from pilot projects to full-scale deployment.
Cost-Benefit Ratio (ROI) 	Compare total system costs to the **financial benefits from improved efficiency**.