👥 End-to-End Team Roles (8 Members, Gap-Free)

1. Domain Expert (Railway SME + Compliance Lead)

- Bring **real-world railway operations knowledge** (precedence rules, signalling, timetable practices).
- Ensure optimization logic aligns with **IR standards & safety regulations**.
- Validate feasibility of “what-if” scenarios.
- Handle compliance & regulatory **judge questions**.

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2. Optimization Engineer (Operations Research Specialist)

- Build mathematical models with **OR-Tools (Python baseline, Rust optional for perf)**.
- Encode constraints: section capacity, precedence, crossing, priorities.
- Ensure **conflict-free feasible schedules**.
- Add **explainability/audit logic** (why a train was prioritized).

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3. AI/ML Engineer (Disruptions + Scenario Simulations)

- Implement **heuristics/ML models** for rapid re-optimization under disruptions (delays, incidents, weather).
- Enable **scenario forecasting + what-if simulation engine**.
- Collaborate with frontend to visualize scenario **playback** (before vs after optimization).

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4. Backend Engineer (APIs + System Glue + Testing)

- Build and expose APIs for:
  - Optimization engine,
  - Simulation engine,
  - Dashboard feeds.
- Integrate with **mock TMS/railway APIs** (since real APIs may not be available).

- Develop **test harnesses** for stress cases (high traffic, cascading delays).
- Ensure system runs in **real-time decision cycles** (< few sec updates).

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5. Frontend/UI Engineer (UX + Visualization)

- Design **controller dashboard** with:
  - Train precedence recommendations,
  - Conflict alerts,
  - Override buttons.
- Develop **interactive simulation playback** (train movement, delays, resolutions).
- Optimize UX to be **judge-friendly** (clear storytelling + easy demo flow).

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6. Data Engineer (Pipelines + Synthetic Data)

- Prepare **clean data feeds**: timetables, rolling stock, train locations.
- Generate **synthetic disruptions** (fog, derailment, loco failure, heavy traffic).
- Ensure consistent pipelines → optimization engine never breaks.
- Provide datasets for **benchmarking throughput & delay metrics**.

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7. Systems/DevOps Engineer (Infra + KPIs)

- Containerize components (**Docker/K8s**).
- Deploy on cloud (AWS/GCP/Azure/NIC cloud) with **CI/CD**.
- Benchmark optimization loop (latency, throughput).
- Build **performance dashboards** with KPIs:
  - Average delay reduction,
  - Throughput (trains/hour),
  - Utilization.

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8. Product/Presentation Lead (Narrative + Pitch)

- Own **judging criteria alignment**:
  - Novelty, Feasibility, Scalability, UX, Sustainability.
- Shape **story arc**:
  Problem → OR/AI solution → Real-time demo → Scalability roadmap.

- Manage deliverables timeline, keep team on track.
- Drive **judges' Q&A prep** (e.g., future integration with live TMS, IR-scale adoption).
