Detailed Project Report
Bokaro Steel Logistics Optimizer

Client: Steel Authority Of India Limited (SAIL)

BSLO

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Contents

Chapter 1

Executive Summary

The **Steel Authority of India Limited (SAIL)** manages one of the largest logistics operations in the country. At the Bokaro Steel Plant alone, thousands of tonnes of steel move every day from stockyards to customer locations across India. This movement heavily depends on rakes — full trainloads of wagons used to carry bulk materials.
Currently, rake formation at Bokaro is mostly manual. Plant teams have to match available inventory, pending customer orders, empty wagon supply, and loading point capacity through phone calls, spreadsheets, and experience.

This leads to frequent challenges:

- Delayed rake formation, missing delivery deadlines.
- Underutilized rakes, with wagons often moving only 60–70% full.
- Higher costs, including penalties and demurrage charges.
- Difficulty in meeting urgent customer orders alongside bulk shipments.

The Bokaro Steel Logistics Optimization (BSLO) project aims to solve these challenges by building an AI/ML-based Decision Support System (DSS). The system will:

- Digitally track inputs: live order details, warehouse inventory, and wagon availability.
- Optimize rake formation using intelligent algorithms that maximize utilization, minimize costs, and prioritize urgent deliveries.
- Provide daily dispatch plans through a simple dashboard that can be directly used by operations managers.

The **expected impact** of BSLO is significant:

- 10–15% reduction in logistics cost by improving rake utilization and minimizing penalties.
- 20–30% improvement in on-time deliveries, leading to higher customer satisfaction.
- Faster decision-making, cutting manual coordination time by up to 50%.
- A scalable system that can later extend from Bokaro to all other SAIL plants.

In short, BSLO is not about replacing human expertise, but about augmenting it with data-driven intelligence. By combining real-time data with optimization techniques, Bokaro Steel Plant can set a new benchmark in efficient, reliable, and cost-effective steel logistics.

Chapter 2

Introduction to Logistics at SAIL

The **Steel Authority of India Limited (SAIL)** is one of India's largest steel producers, with plants and stockyards across the country. Daily, thousands of tonnes of raw materials and finished steel products must move from plants like Bokaro Steel Plant to warehouses, stockyards, and customers—primarily via rail logistics.

Managing this scale is complex, requiring coordination of four key factors simultaneously:

- Customer orders: who needs what, how much, and by when.
- Material availability: stock in warehouses or plants.
- Wagon/rake availability: whether Indian Railways has provided enough wagons.
- Loading point capacity: how many rakes can be loaded at a siding within a time window.

Currently, this **process is manual**. Plant officials spend hours calling, checking spreadsheets, and relying on experience to decide:

- Which orders to prioritize.
- Which stockyard to load from.
- How to combine multiple orders into a single rake.
- Which rake to assign to which route.

Manual decision-making leads to inefficiencies: rakes are underutilized (60–70%), shipments are delayed, costs rise due to demurrage, and priority orders may miss deadlines. Even small inefficiencies translate into significant losses for SAIL.
At Bokaro Steel Plant, managers face constant pressure due to multiple orders, limited siding capacity, and tight timelines. Without a digital system, they rely on guesswork or short-term fixes.

Bokaro Steel Logistics Optimization (BSLO) addresses this by replacing manual coordination with an AI/ML-powered Decision Support System. It can:

- Pull live data from warehouses, orders, and Indian Railways.
- Suggest optimal rake formations automatically.
- Maximize wagon utilization, ensure timely deliveries, and reduce costs.

In short, SAIL's logistics now depend on manual effort. BSLO transforms this into a data-driven system, reducing inefficiencies and setting a model for other plants.

Chapter 3

Objectives of BSLO

The **Bokaro Steel Logistics Optimization (BSLO)** project has one clear aim: to transform the way rake formation is planned and executed at SAIL. Today, this process is highly manual and results in delays, empty wagons, and unnecessary costs. BSLO will act as a Decision Support System, powered by data and AI/ML models, to guide logistics teams in making the best choices every day.

The **specific objectives of BSLO are**:

1. Cost Reduction
    - Minimize freight and transport costs by ensuring rakes are fully loaded.
    - Select the most cost-effective stockyard for each order.
2. On-Time Delivery (SLA Adherence)
    - Meet customer deadlines by automatically considering order priority and delivery schedules.
    - Sequence rake dispatches to align with Service Level Agreements (SLAs).
3. Better Utilization of Resources
    - Ensure wagons and rakes are used at maximum capacity, avoiding partial shipments.
4. Smart Order Clubbing
    - Combine multiple compatible orders into one rake, based on material type, destination, and capacity, so no rake runs half-empty.
    - Decide when to allow multi-destination rakes to improve efficiency.
5. Real-Time Decision Support
    - Pull live data on inventory, rake availability, and order status.
    - Continuously update recommendations when conditions change (e.g., delayed rake arrival, urgent customer order).
6. Optimization Across Rail and Road
    - Suggest whether an order should be fulfilled via rail or road, depending on cost, availability, and timelines.
7. Digital Transparency
    - Replace manual coordination with a centralized, data-driven system.

By meeting these objectives, BSLO will help Bokaro Steel Plant reduce logistics costs by a significant margin, improve customer satisfaction with timely deliveries, and set the foundation for a modern, intelligent logistics system across all of SAIL.

Chapter 4

Proposed System Architecture

The BSLO system has been designed as an end-to-end pipeline that connects raw operational data from Bokaro Steel Plant with an AI-driven optimization engine, and finally delivers actionable logistics decisions to managers.

4.1 Technical Design Overview

1. Input Data Sources

The system begins by collecting data from multiple sources that are currently tracked manually or in silos:

- Inventory Data: Real-time stock levels of finished steel at different stockyards.
- Customer Orders: Pending and new orders with details like material type, tonnage, destination, and SLA deadlines.
- Rake/Wagon Availability: Position, type, and capacity of wagons received from FOIS (Freight Operations Information System).
- Loading Point Details: Availability and throughput of different sidings and loading bays.

This ensures that all critical factors—orders, stock, wagons, and infrastructure—are visible in one place.

2. Data Pipeline & Pre-Processing

The collected inputs are cleaned and standardized into a single format. This step handles missing fields, removes duplicates, and normalizes values like tonnage, dates, and location codes. The result is a unified dataset that can be directly used by the optimization engine.

3. Optimization Engine

At the core of BSLO is the optimization engine, which applies mathematical models and AI-based logic to create the best rake formation plan. The engine works on three parallel goals:

- Cost Efficiency: Calculate transport cost, demurrage, and penalty risks.
- Time/SLA Adherence: Prioritize rakes that help meet urgent delivery deadlines.
- Utilization: Ensure maximum wagon and rake fill to avoid under-loading.

The optimization logic uses techniques like knapsack problem solving (to club orders within rake capacity), greedy heuristics (to quickly allocate resources), and scoring functions (to compare multiple possible plans).

4. Decision Support System (DSS) Layer

The DSS presents the final output in an easy-to-use format for plant managers:

- Daily rake dispatch plans with recommended loading points.
- Suggested order clubbing for full rake utilization.
- Cost and SLA impact estimates for each option.
- “What-if” analysis in case of delays, urgent orders, or sudden rake unavailability.

Managers remain in full control — the system does not replace decision-making but supports it with data-driven insights.

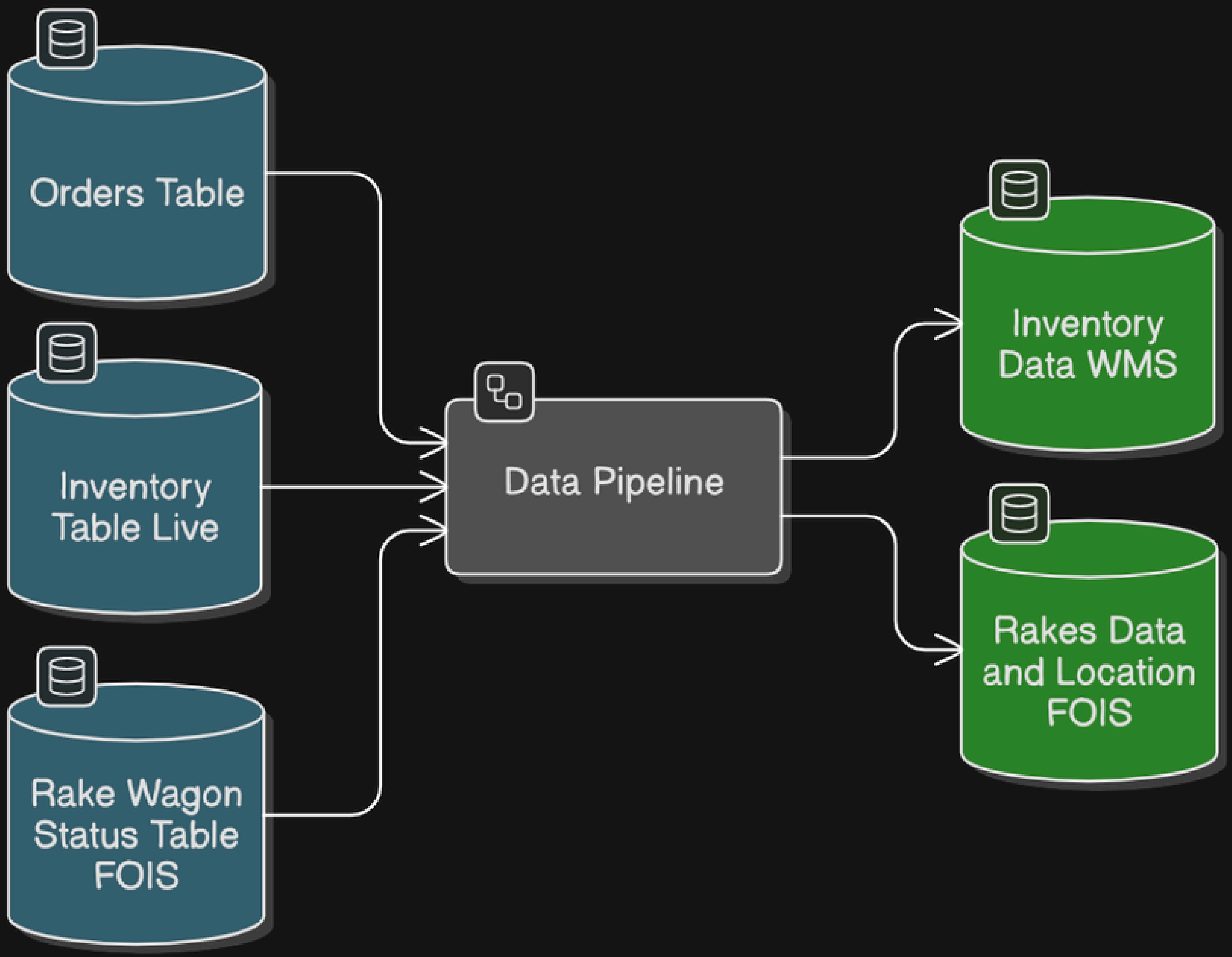
5. Feedback Loop

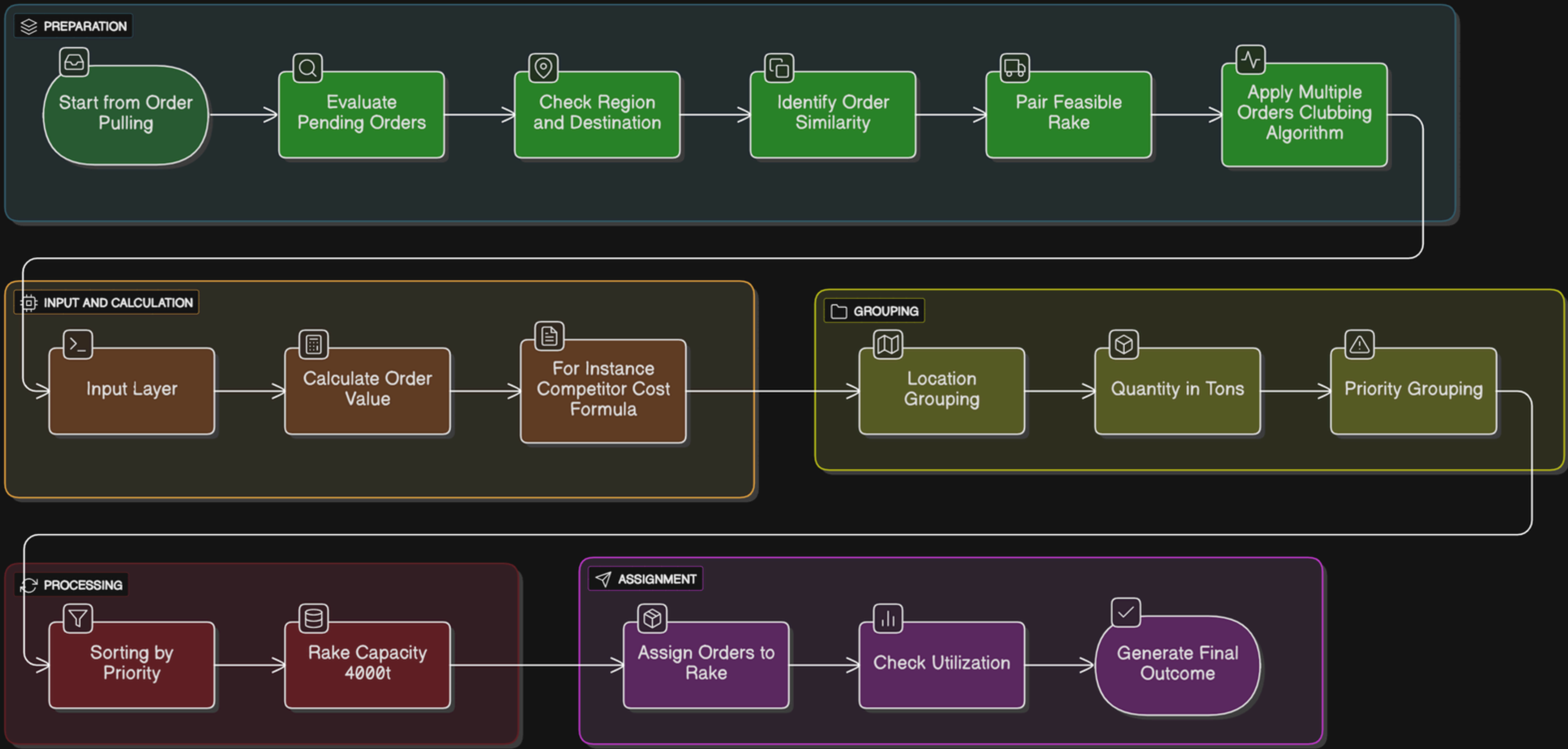
Once the daily plan is executed, the actual outcomes (dispatch time, load %, SLA met/not met) are fed back into the system. This helps BSLO continuously learn and refine its recommendations over time

4.2 End-to-End Workflow

- Order Intake → Capture all pending customer orders (material, tonnage, SLA, destination).
- Inventory Check → Match order requirements with available stock at Bokaro stockyards.
- Rake/Wagon Availability → Fetch wagon count, type, and positions from FOIS.
- Loading Point Capacity → Verify siding and loading bay constraints.
- Data Preprocessing → Clean, validate, and standardize all inputs into a single dataset.
- Order Clubbing → Group compatible orders (by type, SLA, destination) within rake capacity.
- Optimization & Scoring →
- Calculate cost efficiency (freight + penalty risk).
- Check SLA adherence.
- Maximize wagon utilization.
- Best Plan Selection → Rank multiple plans, pick top recommendations.
- DSS Output → Display daily rake formation plan, cost/SLA/utilization scores, and what-if options.
- Execution Feedback → Record actual dispatch vs. planned → feed back for continuous improvement.

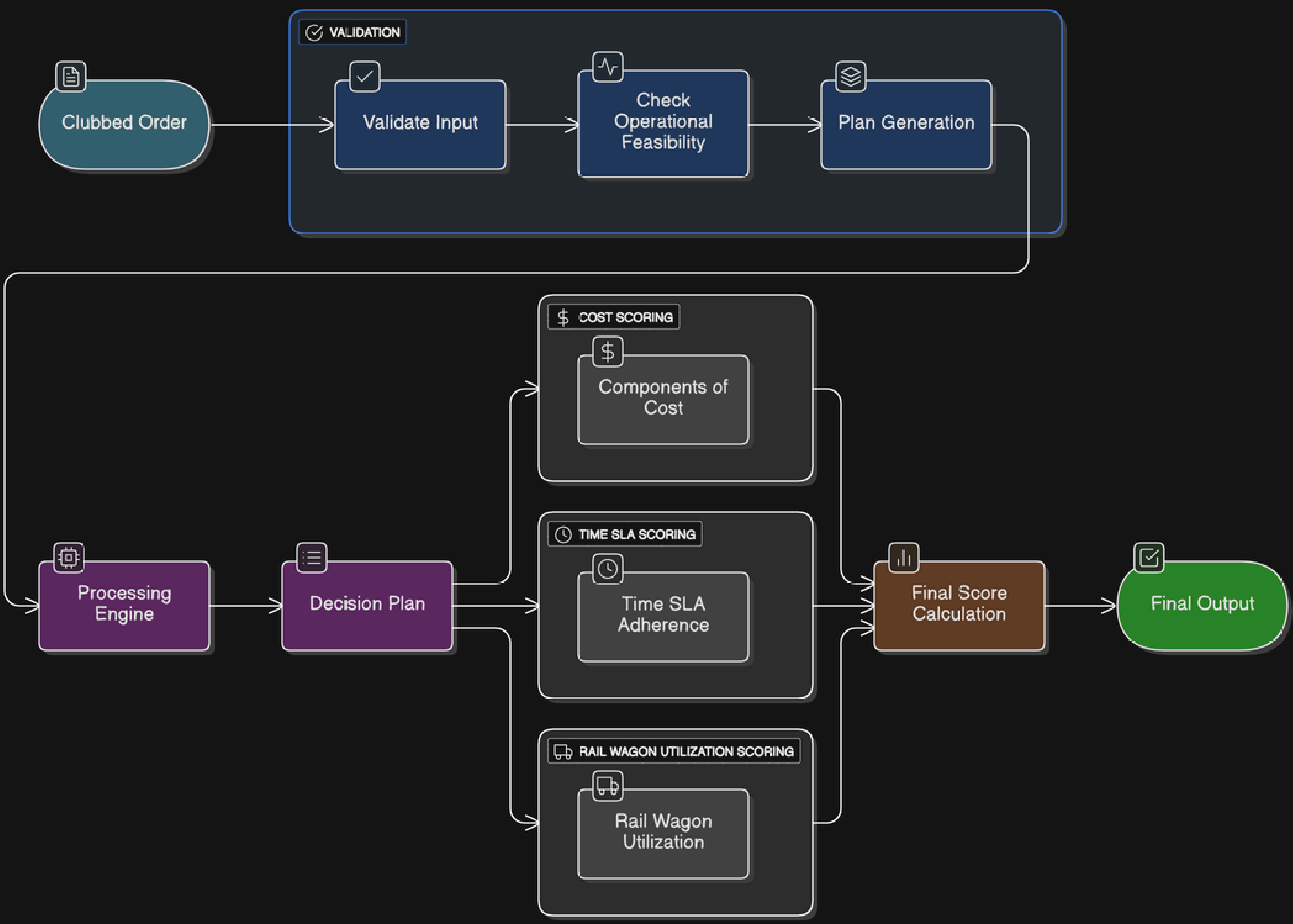
Input Layer Architecture





Clubbing Layer Architecture

Optimization Layer Decision Tree Model Architecture



Chapter 5

Data Sources & Integration

For **BSLO (Bokaro Steel Logistics Optimization)**, data is the foundation of every decision.

The DSS integrates information from multiple existing systems at SAIL bringing together inventory, transport, and order data into one unified decision layer.

Currently, these systems operate independently, causing manual lookups, delays, and mismatch between material availability, rake readiness, and customer demand.
The proposed system digitally connects them through API-based or database-level integrations to ensure real-time visibility and automated decision-making.

1. Stockyard Inventory Systems

- Each stockyard at Bokaro maintains digital records of material type, quantity, and loading bay capacity.
- Data is usually maintained through in-house WMS (Warehouse Management Systems) or manual Excel-based sheets.
- The DSS will automatically fetch daily snapshots or live feeds of:
  - Material name and grade (e.g., HR Coil, TMT Bars)
  - Quantity available (in tonnes)
  - Loading rate per hour / siding capacity
  - Current backlog and rakes already assigned
- This ensures the system only plans dispatches for stockyards with enough inventory and loading bandwidth.

2. FOIS (Freight Operations Information System) – Rail Data

- FOIS is the Indian Railways system used to track rake and wagon availability, movement, and ETA.
- The DSS will integrate FOIS data (through scheduled pulls or API) to get:
  - Number and type of empty rakes available (e.g., BOXN, BCN, BRN)
  - Current rake location and expected arrival at Bokaro
  - Route and destination constraints
  - Loading and unloading status of active rakes
- This allows the system to match each customer order and stockyard with the nearest available rake, reducing idle time and improving SLA adherence.

3. ERP / Order Management Systems

- Customer orders are typically managed within SAIL's ERP system (like SAP) or through a separate Customer Order Database.
- The DSS consumes:
  - Order ID, Customer Name, Destination, Product Type
  - Order Quantity, SLA or due date, and Priority Tag
  - Delivery mode preference (Rail / Road)
- This order data is combined with real-time inventory and rake data to generate feasible loading plans for each day.

4. Warehouse Management System (WMS)

- The WMS provides information on material stacking position, handling time, and loading logistics.
- This helps the DSS to estimate realistic loading durations and avoid overloading specific sidings.
- Data fields typically include:
  - Material ID and stockyard zone
  - Handling time per ton
  - Available cranes/trucks
  - Shift timing and resource availability

5. Integration Layer

All the above data sources flow into a central integration pipeline:
→ Inventory API / Database → FOIS API → ERP/WMS data feeds → Unified Data Lake
The integration pipeline standardizes formats (CSV, SQL, API JSON), validates entries, and makes data available to the Optimization Engine.
 This allows the system to evaluate hundreds of possible rake plans within seconds, using real-time data rather than manual estimates.

Chapter 6

Optimization Framework

At the core of **BSLO** lies the **Optimization Engine** an AI-assisted decision layer that combines Operations Research (OR) techniques with Machine Learning (ML) models to generate, evaluate, and recommend the best rake formation plans for each day.
The system doesn't rely on a single rule. Instead, it runs multiple possible combinations of orders, stockyards, and rakes and scores each based on cost, time, utilization, and priority compliance.

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1. Order Clubbing (Knapsack Optimization)

Before any plan is scored, the system groups compatible orders into rakes.
This is achieved using a Knapsack-style optimization, where:

- Each order acts like an "item" with a specific weight (tonnage) and value (priority or SLA urgency).
- Each rake acts like a "bag" with a fixed capacity (e.g., 4000 tons).

The algorithm fills each rake to maximize total priority and utilization, without exceeding the rake's weight limit.
A combination of greedy heuristics (like First Fit / Best Fit) and Integer Linear Programming (ILP) ensures high efficiency balancing load fill %, distance, and urgency.

2. Plan Evaluation and Scoring

Once rake clubs are formed, each potential dispatch plan is scored using multiple weighted objectives:

- Cost Score: Includes transport, loading, and penalty costs.
- Time Score: Measures SLA adherence and congestion-adjusted travel time.
- Utilization Score: Evaluates how efficiently the rake's capacity is used.
- Priority Compliance Score: Ensures high-priority or export orders are served first.

Each score is normalized (0–10) and combined into a final Weighted Composite Score that decides the best rake formation for execution.

3. Multi-Objective Optimization
Rather than optimizing one goal (like cost) at a time, BSLO uses a multi-objective approach:

- The system finds a balance between low cost, high utilization, and on-time delivery.
- Mathematically, this is done through a weighted sum or Pareto-based optimization, ensuring that no single objective dominates others.
- The model automatically adjusts weights based on operational feedback for example, giving higher weight to SLA adherence during export periods.

4. AI/ML Enhancement
Machine learning modules enhance the optimization process by:

- Predicting rake arrival and loading times using historical FOIS and yard data.
- Forecasting order demand based on seasonality and production schedules.
- Learning from past plans to identify which rake formations consistently performed best.

Over time, BSLO becomes a self-learning decision support system, improving accuracy and responsiveness each day.

Outcome
The result is a data-driven, adaptive framework that:

- **Fills more rakes fully,**
- **Reduces demurrage and idle cost,**
- **Improves delivery reliability, and**
- **Transforms manual logistics planning into an automated, optimized, and explainable system.**

Chapter 7

Decision Support Features

The dashboard suite provides real-time visibility into order status, rake availability, and dispatch performance through intuitive analytics panels. Interactive "What-If" simulators and scenario planners allow users to adjust parameters (demand, delays, priorities) and instantly visualize optimized plans, costs, and utilization impacts. Experience the live dashboard @ https://www.sahilghodvinde.in/bslo/dashboard

BSLO   Dashboard   Orders   Rakes   Inventory   Reports   Settings

Bokaro Steel Logistics Optimization Dashboard

Last Updated: 2024-01-26 14:35

Summary

Pending Orders	Available Rakes	Stockyard Inventory	Today's Dispatch Plan
125	8	45,000 Tons	15 Rakes
-5%	+10%	-2%	+8%

Orders Panel

ORDER ID	MATERIAL	QUANTITY	DESTINATION	PRIORITY	STATUS
ORD-2024-001	Steel Coils	500 Tons	Mumbai	High	Pending
ORD-2024-002	Steel Beams	300 Tons	Delhi	Medium	Processing
ORD-2024-003	Steel Plates	200 Tons	Chennai	Low	Confirmed
ORD-2024-004	Steel Rods	400 Tons	Kolkata	High	Pending
ORD-2024-005	Steel Sheets	150 Tons	Bangalore	Medium	Processing

Generated Rake Formation Plans

Plan A Recommended

Clubbed Orders: ORD-2024-001, ORD-2024-004
Stockyard: Bokaro, Destination: Mumbai
Assigned Rake: Rake 101, Capacity Utilization: 95%
ETA: 2024-01-28 10:00
Score: Cost(90%) Time(85%) Util(98%) Prio(92%)

Plan B

Clubbed Orders: ORD-2024-002, ORD-2024-005
Stockyard: Dhanbad, Destination: Delhi
Assigned Rake: Rake 102, Capacity Utilization: 80%
ETA: 2024-01-28 14:00
Score: Cost(85%) Time(90%) Util(80%) Prio(88%)

Rake & Wagon Availability

Rake 101
Bokaro, ETA: 2024-01-27 08:00
Capacity: 1000 Tons

Rake 102
Dhanbad, ETA: 2024-01-27 12:00
Capacity: 1200 Tons

Rake 103
Ranchi, ETA: 2024-01-27 16:00
Capacity: 800 Tons

Inventory Snapshot

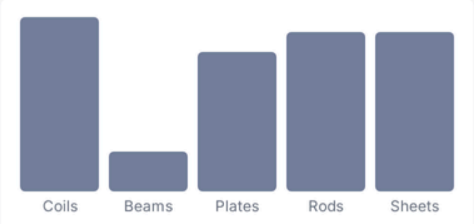
Final Dispatch Recommendation

Recommended Plan: Plan A

Clubbed Orders: ORD-2024-001, ORD-2024-004. Rake 101, 95% utilization. ETA: 2024-01-28 10:00

Confirm Dispatch

Inventory Snapshot



What-If Simulator

Demand (%)

Rake Arrival Delay (Hours)

Priority Prioritization (%)

Re-Generate Plans

Plan Overview

Included Orders

- ID: ORD-001, Customer: Tata Steel, Qty: 500T, SLA: 2 days, Prio: High
- ID: ORD-002, Customer: JSW Steel, Qty: 300T, SLA: 3 days, Prio: Medium

Assigned Rake

Rake #123 (Capacity: 1000T, Utilization: 80%)

Source & Destination

Bokaro Stockyard → Mumbai, Delhi

Projected ETA

2024-01-30, 14:00

Score Breakdown (Weighted: 88.5)

Cost	92
Time	85
Utilization	80
Priority	95

Train Visualization

Impact Preview (Before vs After)

Utilization	Cost	SLA Compliance
75% → 80%	$1.2M → $1.1M	90% → 88%

Changeable Parameters

Order Assignment

- [x] ORD-001 (Tata Steel, 500T)
- [x] ORD-002 (JSW Steel, 300T)
- [ ] ORD-003 (SAIL, 200T)

Rake Choice

Rake #123 (1000T)

Stockyard Source

Bokaro Stockyard

Priority Weights

Cost

Time

Utilization

Priority

SLA Relaxation (Optional, in hours)

e.g., 12

Recalculate Plan

Cancel / Close | Save as New Plan | Replace Current Plan

Chapter 8

Expected Outcomes & Benefits

Key Performance Improvements:

- Optimized Rake Utilization: Dynamic order clubbing and load balancing improve utilization by up to 15–20%, reducing empty runs and idle capacity.
- Reduced Operational Costs: AI + OR algorithms minimize cost through efficient load allocation, route selection, and inventory control.
- Faster Dispatch & Turnaround: Automated plan generation cuts decision time from hours to minutes, accelerating dispatch readiness.
- Improved SLA Compliance: Predictive alerts prevent bottlenecks, improving on-time delivery and reliability.
- Better Stakeholder Visibility: Real-time dashboards and simulation tools enhance coordination across stockyards, operations, and management.

What Makes Our Solution Stand Out:

- Hybrid Optimization Engine: Combines AI/ML learning (demand prediction, scoring) with Operations Research algorithms (multi-objective optimization, knapsack, linear assignment) for actionable decisions.
- "What-If" Simulator: Enables scenario-based decision-making users can tweak constraints (like train delays or priority changes) and instantly see impact.
- Adaptive Learning Layer: System continuously learns from past dispatch data, improving future rake formation accuracy and cost efficiency.
- End-to-End Decision Support Platform: From data ingestion → optimization → visualization → real-time re-planning all in one unified system.

Chapter 9

Future Scope & Scalability

The proposed system is not just a one-time optimization tool it's the foundation for a self-learning, AI-powered logistics ecosystem for SAIL and beyond. As we move toward pilot deployment at Bokaro Steel Plant, the next phase focuses on scaling intelligence, automation, and integration.

1. Continuous Learning through ML Feedback Loops

- Every dispatch cycle feeds back into our data models — allowing the system to learn from past outcomes, improve accuracy, and adapt to seasonal or demand-based variations.
- Predictive models will evolve to forecast order surges, rake delays, and demand hotspots, turning logistics planning into a proactive rather than reactive process.

2. Intelligent Decision Reinforcement

- Incorporating reinforcement learning will enable the system to simulate thousands of rake formation possibilities and automatically choose those that maximize multi-objective goals cost, utilization, and SLA compliance.

3. Cross-Plant Scalability

- The same optimization engine can scale seamlessly across other SAIL plants (e.g., Durgapur, Rourkela, Bhilai) with minimal configuration, as it relies on modular data pipelines and standardized logistics schemas.
- Inter-plant coordination can further unlock network-level optimization, where rakes are shared and scheduled dynamically across plants.

4. Integration with National Rail and ERP Systems

- Future versions will integrate with Indian Railways APIs, SAIL ERP systems, and IoT-enabled wagons for real-time visibility into rake status, stockyard conditions, and in-transit tracking.
- This creates a connected, intelligent supply chain that reacts instantly to operational events.
- Over time, this reduces human intervention to only oversight and exception handling, leading to a self-optimizing logistics ecosystem.

Bokaro Steel Logistics Optimizer

Towards Smarter, Safer, and Sustainable Rake formation

BSLO

Prepared and Updated by
Team Devkstra
September 2025