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(51) International classification	:B61B0001020000, G06Q0010040000, G06N0005045000, G05B0013020000, G06N0020000000	(71)**Name of Applicant :** **1)SRJX RESEARCH AND INNOVATION LAB LLP** Address of Applicant :Plot No - 3E/474, Sector-9, CDA, Post- Markat Nagar, Cuttack- 753014, Odisha, India Cuttack Orissa India (72)**Name of Inventor :** **1)DR SOUMYA RANJAN JENA**
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(57) Abstract :
The present invention relates to an Artificial Superintelligence-Based Railway Station Platform (ASI-RSP) system and method for autonomous, adaptive, and safe management of railway stations. The system integrates multimodal sensing, digital twin simulation, and reinforcement-learning-based decision optimization to monitor, predict, and control station operations in real time. Sensor fusion modules collect visual, acoustic, lidar, radar, and environmental data to generate a unified situational map. An Artificial Superintelligence Core performs predictive modeling, causal reasoning, and policy generation, while a Human-Over-the-Loop Console provides supervised review and explainable decision support. The Actuation Layer executes approved control actions for platform screen doors, gates, escalators, HVAC, and signage, with continuous feedback ensuring adaptive recalibration. The invention enables privacy-preserving analytics, predictive maintenance, and energy optimization while maintaining compliance with safety and ethical standards. The ASI-RSP thereby achieves autonomous yet human-supervised station operation with enhanced safety, efficiency, and sustainability.

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FORM 2

THE PATENTS ACT, 1970

(39 OF 1970)

AND

THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(*See* section 10; rule 13)

1. TITLE OF THE INVENTION

ARTIFICIAL SUPERINTELLIGENCE-BASED RAILWAY STATION PLATFORM

2. APPLICANT

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3. PREAMBLE TO THE DESCRIPTION

The following specification particularly describes the invention and the manner in which it is to be performed.

FIELD OF THE INVENTION

The present invention relates to an Artificial Superintelligence-Based Railway Station Platform (ASI-RSP) designed to unify perception, prediction, optimization, and actuation functions across safety-critical and service domains of a passenger railway platform. The invention provides a high-level autonomous control and monitoring system capable of continuously orchestrating platform safety, train-alignment coordination, passenger-flow regulation, and service optimization through a verified Artificial Superintelligence (ASI) controller that maintains a continuously updated digital twin of the entire station environment.

BACKGROUND OF THE INVENTION

Conventional railway station management systems rely on multiple siloed subsystems such as CCTV analytics, platform screen-door (PSD) control units, public-address systems, timetable schedulers, ticketing and access gates, crowd counters, and SCADA/ATS interfaces. These are often sourced from different vendors and loosely integrated through middleware or human operating procedures. Coordination across these subsystems remains fragmented, with each operating on pre-set logic or fixed decision rules. For instance, a vision module may detect overcrowding while the scheduler continues to dispatch trains at planned headways or PSDs may open and close on fixed timings irrespective of real-time boarding densities.

Modern artificial intelligence (AI) and computer vision tools have been introduced for specific tasks such as obstacle detection, people counting, railcar inspection or timetable prediction. However, these implementations are narrow, perception-centric and task-specific. They typically optimize single metrics like detection accuracy or throughput without modelling higher-level safety and operational trade-offs such as hazard likelihood, evacuation complexity, or dwell-time elasticity. These models tend to degrade under conditions of uncertainty or during unplanned disruptions such as mass gatherings, medical emergencies, monsoon-related delays, or concurrent upstream congestion.

Prior decision engines in station systems typically rely on rule-based control or fixed decision trees for operations such as PSD opening profiles, alarm escalation, and passenger flow limits. Such logic is brittle and fails to adapt to multi-variable, concurrent anomalies. When rare or compound events occur—such as a medical incident near the edge line during simultaneous train arrival and equipment malfunction legacy systems lack the reasoning capability to balance competing objectives like safety, punctuality, accessibility, and energy conservation.

Sensor fusion within prior art systems is shallow and limited. Data streams from heterogeneous sensors such as cameras, radar/lidar, microphones, ticketing taps, PSD encoders, and wearable devices are often processed independently or combined through simple confidence-weighted averages.

Data streams from heterogeneous sensors such as cameras, radar/lidar, microphones, ticketing taps, PSD encoders, and wearable devices are often processed independently or combined using naïve fusion techniques such as *linear confidence-weighted averaging*, wherein each sensor's output (e.g., detection score or measured parameter) is multiplied by a heuristic confidence coefficient derived from recent accuracy or reliability metrics, and the weighted values are summed and normalized to obtain a composite estimate. The term "confidence-weighted averaging" herein refers to a statistical fusion process in which each sensor output is assigned a quantitative confidence coefficient (ranging from 0 to 1) proportional to its estimated reliability, signal-to-noise ratio, calibration accuracy, or recent validation score.

This results in weak situational awareness, susceptibility to occlusions or lighting variance, and poor handling of uncertainty. False negatives and false alarms are frequent, leading to "alert fatigue" among human operators. In many cases, there are no graceful fallback mechanisms; when system confidence drops, the software neither switches to safe modes nor requests targeted human intervention.

Human operators therefore remain central to interpreting numerous dashboards and alerts, correlating conflicting key performance indicators (KPIs), and manually issuing commands across disparate subsystems. This leads to cognitive overload, delayed responses, and inconsistent actions especially during disruptions or peak passenger loads.

Accessibility support within prior systems is typically implemented as an auxiliary feature rather than an integrated control layer. Assistive facilities such as tactile paths, ramps, or reserved boarding zones operate independently and are not dynamically synchronized with real-time platform or train conditions. As a result, accessibility provisions may be misaligned, for example, ramps deploying at incorrect times or announcements lacking multimodal clarity.

Similarly, predictive maintenance and energy optimization systems in prior art function in isolation from crowd and safety management modules. Maintenance scheduling may conflict with passenger flow requirements, while lighting and HVAC control systems are optimized for energy use without accounting for safety visibility or comfort constraints. The absence of a unified optimizer across safety, operations, energy, and maintenance domains increases lifecycle costs and reduces resilience during component failures.

Cybersecurity, data privacy, and auditability are also underdeveloped in existing systems. Many solutions transmit raw video or sensor data to cloud servers, leading to privacy and bandwidth concerns. Model updates and learning pipelines are opaque, with little traceability or assurance of safety. Security mechanisms are often limited to perimeter monitoring and do not detect runtime anomalies such as sensor spoofing, clock drift, or adversarial input attacks. During incidents, reconstructing the sequence of automated and human decisions is difficult, complicating root-cause analysis and regulatory compliance.

Collectively, existing station-management systems suffer from fragmented control, narrow perception capabilities without prescriptive and risk-bounded actions, brittle rule-based logic, weak causal fusion and uncertainty handling, limited inclusivity and co-optimization across safety and energy domains, and inadequate provisions for cybersecurity, privacy, and audit trails. These limitations result in slow, inconsistent, and occasionally unsafe responses during peak passenger flows, system disruptions, and emergency situations.

OBJECTS OF THE INVENTION

The principal object of the present invention is to provide an Artificial Superintelligence-Based Railway Station Platform (ASI-RSP) that autonomously manages station operations through perception, prediction, optimization, and actuation within a closed cognitive loop, thereby eliminating the limitations of human-dependent and rule-based control systems.

Another object of the invention is to develop a unified cognitive controller capable of integrating heterogeneous data from CCTV, lidar, radar, acoustic, and environmental sensors to generate a fused, real-time situational awareness model of the station environment.

Another object of the invention is to provide a predictive modelling framework employing temporal-spatial learning and causal reasoning for forecasting passenger flow, congestion, and train alignment deviations, enabling pre-emptive and context-aware control actions.

Yet another object of the invention is to implement a multi-objective optimization engine that determines safety-verified, energy-efficient, and passenger-friendly decisions using reinforcement learning under formal safety constraints.

One further object of the invention is to establish a continuously synchronized digital twin of the railway platform that mirrors all physical and environmental entities, enabling real-time simulation, verification, and impact assessment of control actions before execution.

Another object of the invention is to ensure deterministic, low-latency actuation for safety-critical subsystems such as platform screen doors, lighting, ventilation, and passenger guidance systems, supported by acknowledgment-based feedback loops.

One other object of the invention is to provide formal verification and self-integrity mechanisms that guarantee provable safety, detect anomalies, and enforce certified fallback operations during sensor or network failures.

A further object of the invention is to incorporate predictive maintenance and energy optimization within the operational logic, enabling early fault detection, micro-downtime scheduling, and sustainable energy utilization.

Another object of the invention is to employ federated and privacy-preserving learning for continuous system improvement without centralizing raw passenger data, thereby ensuring compliance with privacy and data-protection standards.

One other object of the invention is to maintain human oversight through a Human-Over-the-Loop console that provides explainable AI reasoning, transparent audit trails, and secure manual override capabilities.

Another object of the invention is to enable multi-platform orchestration, facilitating synchronized crowd distribution, coordinated evacuation management, and network-level optimization across interconnected stations.

A Further object of the invention is to ensure that the entire system operates within established railway safety, cybersecurity, and ethical AI governance standards, maintaining accountability, traceability, and regulatory compliance.

SUMMARY OF THE INVENTION

The present invention provides an Artificial Superintelligence-Based Railway Station Platform (ASI-RSP) system that establishes a self-governing, cognitive, and safety-certified framework for intelligent station management. The invention overcomes the operational limitations of human-dependent and rule-based control systems currently deployed in railway stations by integrating perception, prediction, optimization, and actuation into a unified closed-loop architecture.

The ASI-RSP comprises a layered intelligence stack including (i) a perception sub-layer for multimodal sensor fusion and environmental understanding, (ii) a predictive modeling framework for anticipating passenger and train dynamics, (iii) an optimization layer employing multi-objective decision logic, and (iv) an actuation layer ensuring deterministic and verified control execution.

A continuously synchronized digital twin models passengers, trains, devices, and environmental conditions, allowing the controller to simulate and evaluate multiple control scenarios prior to actuation. Safety is assured through formal verification, fail-safe fallback mechanisms, and watchdog integrity checks, ensuring uninterrupted and risk-bounded operation even under degraded conditions.

The invention further integrates predictive maintenance, energy optimization, and federated learning for continuous adaptation without centralizing raw data, thereby ensuring privacy, scalability, and resilience. The ASI-RSP supports multi-platform orchestration, enabling coordinated crowd management, dynamic dwell-time recovery, and efficient evacuation handling.

The system's human-over-the-loop design maintains transparency, accountability, and compliance with ethical AI principles, while adhering to railway safety and cybersecurity standards. By combining adaptive intelligence, verified safety, and sustainable energy management, the ASI-RSP provides a transformative advancement in autonomous railway station operation.

BRIEF DESCRIPTION OF DRAWINGS

Fig 1: Detailed Flow Chart

1. Artificial Superintelligence (ASI) Core

a. **Role:** Serves as the supervisory "brain" of the platform that defines high-level objectives, orchestrates subordinate models, and supervises ongoing learning and simulation. The ASI Core does not directly command hardware; it configures, coordinates, and ensures that all downstream layers remain aligned with global goals and safety constraints.

b. **Main Components:**

- **Digital Twin Orchestrator:** Generates and controls high-fidelity station simulations representing normal, peak, and disrupted operating conditions for planning, training, and stress testing.
- **Causal Modeling Engine:** Learns and maintains cause–effect relationships between variables (e.g., gate metering and platform density) to enable counterfactual and "what-if" analysis.
- **Objective Composer:** Formulates and balances multi-objective optimization criteria including safety, punctuality, accessibility, energy efficiency, and maintenance into a coherent goal scorecard transmitted to the Policy Layer.
- **Knowledge Graph and Policy Memory:** Stores spatial layouts, asset metadata, operational constraints, incident logs, and historically validated control policies for fast retrieval and contextual reasoning.
- **Model Registry and Governance Module:** Maintains version-controlled models, validation records, and cryptographic sign-offs to ensure model provenance, rollback capability, and compliance with runtime safety protocols.

c. **Inputs:** Aggregated station state (from the State Estimation Layer), safety alerts (from Runtime Safety), and operator intents.

d. **Outputs**: Global objectives, simulation-derived priors, and policy templates/hyperparameters forwarded to the Policy Generation Layer.

2. Sensor Fusion and Perception (Edge Layer)

a. **Role:** Performs privacy-preserving, low-latency perception of the physical environment at the platform and station edge.

b. **Main Components:**

- **Ingest and Time Synchronization Module:** Integrates and time-aligns sensor inputs from CCTV, thermal cameras, radar, LiDAR, microphones, ticketing systems, train telemetry, platform screen door (PSD) encoders, wearable beacons, and environmental probes.

- **Calibration and Health Module:** Performs sensor calibration, drift correction, and liveness validation.
- **Privacy Redaction Unit:** Applies on-device face/body blurring, voice obfuscation, and token hashing to ensure that personally identifiable information (PII) never leaves the edge.
- **Feature Extractors:** Detects and classifies passengers, queues, object hazards, and behavioral patterns; generates density heatmaps, flow vectors, dwell time estimates, and door alignment cues.
- **Multi-Sensor Fusion Engine:** Performs confidence-weighted fusion of heterogeneous sensors (e.g., radar for occlusions, vision for semantic detail).
- **Edge Attestation:** Ensures code and model integrity via secure boot, telemetry signing, and attestation protocols.

c. **Inputs:** Raw sensor streams.

d. **Outputs:** Clean, redacted, time-aligned feature sets and confidence/health metadata for State Estimation.

3. State Estimation Layer (Live Digital Twin)

a. **Role:** Transforms fused perceptual features into a coherent, predictive model of the live station environment—effectively the operational "digital twin."

b. **Main Components:**

- **Multi-Target Tracking Module:** Employs Kalman and particle filters with identity re-association to prevent double-counting under occlusion.
- **Occupancy and Pressure Mapping:** Produces dynamic spatial grids of people density, flow directionality, and edge proximity.
- **Queue and Dwell Estimators:** Estimates queue lengths, waiting times, and train dwell/door dwell projections.
- **Risk Scoring Engine:** Computes probabilistic risk scores for slip/fall, crush, and intrusion hazards, as well as accessibility friction metrics.
- **Throughput and Elasticity Models:** Quantifies correlations between entry metering and downstream crowd densities.

- **Uncertainty Engine**: Attaches confidence intervals to each variable for use in safety verification and model-predictive control (MPC).

c. **Inputs:** Fused perception features and train telemetry/schedules.

d. **Outputs:** Structured station "state vector" with uncertainty parameters used as the single source of truth for Policy Generation and active sensing feedback.

4. Policy Generation Layer (Reinforcement Learning + Model Predictive Control)

a. **Role:** Generates control actions that optimize multiple objectives subject to real-time safety, fairness, and regulatory constraints.

b. **Main Components:**

- **Multi-Objective Reward Composer:** Encodes hierarchical priorities (e.g., safety > accessibility > punctuality > energy efficiency) into scalarized reward functions.
- **Model Predictive Control (MPC):** Solves short-horizon optimizations (typically 60–180 seconds) using real-time station dynamics.
- **Safe Reinforcement Learning Module:** Trains and adapts control policies in simulation (offline) and under safety supervision (online).
- **Constraint and Fairness Manager:** Enforces hard constraints and accessibility provisions, ensuring equitable passenger treatment.
- **Policy Explainer:** Generates interpretable rationales for human operators.
- **Safety Shields:** Invokes runtime monitors before command dispatch to ensure conformance with formal safety invariants.

c. **Inputs:** State vector and ASI objectives.

d. **Outputs:** Candidate action sets with explanations, forwarded to Runtime Safety and the Human Console.

5. Runtime Safety and Cyber Assurance Layer

a. **Role:** Functions as the terminal safety and security barrier, validating every control command before execution.

b. **Main Components:**

- **Formal Safety Invariants:** Enforces provable runtime constraints (e.g., PSD door interlocks tied to train position and speed thresholds).
- **Anomaly and Spoofing Detectors:** Monitors for model drift, data spoofing, or timing anomalies.
- **Command Journal and Signing Module:** Cryptographically signs and timestamps all control actions and model updates for auditability.
- **Zero-Trust Cyber Framework:** Implements mutual TLS, role-based access control, and secure enclaves for critical computation.
- **Graceful Degradation Logic:** Reverts to deterministic safe modes (e.g., static headways) upon loss of confidence or connectivity.
- **Incident Bridge:** Generates alerts and executes hard interlocks when safety thresholds are breached.

c. **Inputs:** Candidate actions, state vectors, and system health indicators.

d. **Outputs:** Verified commands to Actuation Layer; alerts to ASI Core and Human Console.

6. Actuation Layer

a. **Role:** Executes validated control actions and provides feedback telemetry for closed-loop correction.

b. **Actuator Families:**

- **Platform Screen Doors (PSD)**
- **Signage and Public Address (PA)**
- **Entry/Exit Gates and Flow Baffles**
- **Escalators and Elevators**
- **Lighting and HVAC systems**
- **Robotic or human staff interfaces**
- **ATS/Signaling coordination hooks**

c. **Interfaces:** Implements SCADA, OPC-UA, and Modbus wrappers; employs handshake-based command acknowledgments; supports watchdogs and manual emergency overrides.

d. **Inputs:** Approved control commands.

e. **Outputs:** Acknowledgments, actuator states, and performance telemetry to the State Estimation Layer.

7. Human-Over-the-Loop Console

a. **Role:** Enables transparent human oversight, policy approval, and continuous operator learning.

b. **Main Components:**

- **Explainable User Interface:** Displays action rationales, uncertainty levels, and comparative risk visualizations.
- **Role-Based Approval Workflow:** Automates routine approvals and escalates high-impact decisions to supervisors.
- **Simulation Sandbox:** Allows operators to test control strategies within accelerated digital-twin simulations.
- **Runbooks and Playbooks:** Provides standardized responses for recurring incidents (e.g., lift failure, late arrivals).
- **Accessibility Features:** Offers adaptive UI with localized and inclusive design.
- **Audit and Training Subsystem:** Facilitates playback of historical incidents for training and policy improvement.

c. **Inputs:** System-generated explanations, alerts, and policy recommendations.

d. **Outputs:** Operator approvals, overrides, and preferences fed back to Policy Generation, Perception, and ASI Core.

Fig 2: **Architecture**

The diagram illustrates the integrated architecture of an AI-driven railway station management system that uses Artificial Superintelligence (ASI) to monitor, predict, and control the station environment autonomously and safely.

It merges real-time perception, human oversight, and autonomous decision-making to ensure crowd safety, efficiency, and operational reliability.

1. Artificial Superintelligence-Based Railway Station Platform

This topmost block represents the entire intelligent control ecosystem governing the railway platform. It serves as the central orchestrator of all subsystems and decision flows.

Core Functions:

- Coordinates data exchange between subsystems.
- Defines operational goals such as safety, crowd management, punctuality, and energy optimization.
- Supervises AI Core, Sensor Fusion, Actuation, and Human Console.

2. **AI Core:** The AI Core is the brain of the system — it performs complex cognitive reasoning, learning, and decision-making.

Functions:

- Digital Twin Modelling: Creates a live virtual model of the entire station environment for continuous prediction and simulation.
- Causal Modelling: Identifies cause–effect relations (e.g., "Gate congestion → platform crowding").
- Policy Generation: Uses Reinforcement Learning and Model Predictive Control (MPC) to suggest safe, efficient control actions.
- Optimization Engine: Balances multiple objectives—safety, efficiency, accessibility, and sustainability.

Output: Generates policy directives that are sent to the Sensor Fusion and Actuation modules for implementation.

3. Sensor Fusion & Perception: This module bridges the physical environment and the digital intelligence system.

Inputs:

- CCTV and thermal cameras.
- LiDAR, radar, microphones, crowd sensors.
- Environmental sensors (temperature, CO_2, light, etc.).
- Ticketing and gate data.

Functions:

- Edge Analytics: Processes data locally for faster decisions.
- Privacy Redaction: Masks faces, anonymizes data before transmission.
- Fusion Engine: Combines multi-sensor inputs to create unified situational awareness.
- Object Detection: Identifies people, obstacles, hazards, or anomalies.

Output: Real-time perception map → fed to AI Core and Human Console for analysis and action.

4. Actuation System: The Actuation Layer translates AI decisions into real-world actions that directly influence station behaviour.

Controlled Devices:

- Platform Screen Doors (PSD): Open/close dynamically for safety.
- Signage & Displays: Direct passenger flow, inform delays.
- HVAC Systems: Adjust air, lighting, and temperature based on crowd density.
- Escalators & Gates: Modify speed or access flow dynamically.
- Automated Train Interface: Coordinate dwell times, departure sequencing.

Feedback Loop:

Each actuator sends performance and confirmation data back to the AI Core for monitoring and recalibration.

5. **Human-Over-the-Loop Console**

The Human Console ensures ethical and explainable AI control through supervised human decision-making.

Functions: Displays system explanations and recommendations from the AI Core.

- Allows supervisors to approve, override, or modify policies before execution.
- Provides visual simulation (via digital twin) before implementation.
- Records actions for auditing and model training.

Feedback Mechanism:

- Operators' decisions (approvals or rejections) are fed back to the AI Core, helping it learn human-aligned policies for future automation.

6. **Operational Workflow**

- Data Acquisition: Sensors capture visual, audio, and environmental data.
- Perception & Fusion: Sensor Fusion system processes and merges data streams.
- Analysis & Prediction: AI Core simulates the environment via the digital twin.
- Decision & Policy Generation: Core models generate optimized, safe control actions.
- Human Supervision: Console displays AI decisions; humans review/approve.
- Execution: Actuation layer performs control actions (signage, gates, PSDs, etc.).
- Feedback Loop: Sensor data updates the system continuously for real-time adaptation.

7. Platform-Level Example

- When passenger density increases beyond a safety threshold,
  - Sensors detect crowd pressure.
  - AI Core predicts congestion risk.
  - Policy Generation decides to slow escalators and increase gate metering.
  - Human Console confirms action.
  - Actuators implement controls (signage changes, door delays).
  - Feedback verifies reduced density → model updates.

8. Benefits

- Autonomous yet supervised operations.
- Real-time adaptive control under varying crowd conditions.
- Privacy-preserving analytics.
- Reduced human workload with transparent explainability.
- High safety, efficiency, and sustainability compliance.

Fig 3: System Architecture Diagram: Fig 3 illustrates the complete system architecture of the ASI-RSP. The platform integrates sensing, artificial intelligence reasoning, safety assurance, human supervision, and actuation into a closed-loop intelligent ecosystem designed to monitor, predict, and control all activities on a railway platform in real time.

1. Sensors

a. **Function:** The sensing layer constitutes the perceptual foundation of the system, acquiring environmental, operational, and passenger-related data from diverse modalities.

b. **Components include:**

- **CCTV and Thermal Cameras:** Detect crowd density, motion, and hazardous events.
- **LiDAR and Radar Units:** Generate three-dimensional spatial maps and distance measurements for precise object localization.
- **Acoustic Microphones:** Detect and classify auditory anomalies such as distress calls, alarms, or structural noises.
- **Ticketing and Access Systems**: Provide entry/exit data streams for modeling passenger inflow and outflow.
- **Environmental Sensors**: Measure ambient conditions such as air quality, luminance, temperature, and humidity.

c. **Output:** Raw multimodal data streams are transmitted to the Sensor Fusion and Perception Module for preprocessing and redaction.

2. Sensor Fusion and Perception Layer

a. **Function:** Converts heterogeneous sensor inputs into structured, privacy-preserving situational information usable by higher-level AI components.

b. **Processes include:**

- **Edge Analytics:** Executes low-latency computation proximal to sensors to minimize round-trip delay.
- **Privacy Redaction:** Removes or masks personally identifiable information (faces, voices) prior to off-device transfer.
- **Fusion Algorithms:** Combine multi-sensor data (video, radar, acoustic, environmental) into a coherent spatio-temporal model.
- **Anomaly Detection:** Identifies abnormal motion, crowding, or safety-critical deviations.

c. **Output:** A fused, redacted perception map is generated and supplied to the State Estimation Unit and AI Core.

3. **State Estimation Unit**

a. **Function:** Constructs and maintains a live digital twin of the railway platform environment.

b. **Core Tasks:**

- **Crowd Modeling:** Determines real-time density, velocity, and direction of passenger flow.
- **Risk Assessment:** Predicts short-term hazards such as slip, crush, fall, or congestion events.
- **Queue Management:** Estimates queue lengths and waiting times at gates or elevators.
- **Elasticity Modelling:** Evaluates system responsiveness to operational changes such as gate metering or platform redistribution.

c. **Output:** A structured state vector representing key system parameters (e.g., crowd pressure, occupancy, safety margins) is transmitted to the AI Core and Policy Generation Layer.

4. **AI Core**

a. **Function:** Serves as the cognitive and supervisory intelligence of the ASI-RSP, responsible for high-level understanding, forecasting, and decision synthesis.

b. **Principal Operations:**

- **Digital-Twin Simulation:** Continuously replicates station conditions in silico to predict and test operational responses.
- **Causal Modeling Engine:** Learns and encodes cause–effect relationships (e.g., "Escalator slowdown reduces platform density by X%").
- **Policy Formulation:** Balances multi-objective criteria—safety, throughput, accessibility, comfort, and energy—into optimized strategies.
- **Self-Learning Feedback Loop:** Adapts internal models through reinforcement from observed outcomes and operator interventions.

c. **Output:** Generates high-level control policies and decision priorities, which are forwarded to the *Policy Generation Layer* and *Runtime Safety and Cyber Assurance Module.*

5. Policy Generation Layer

a. **Function:** Translates the cognitive strategies of the AI Core into concrete, executable control actions**.**

b. **Processes:**

- **Reinforcement Learning Engine:** Learns operational policies through simulation and controlled real-world adaptation.
- **Model Predictive Control (MPC):** Performs rolling-horizon optimization over short-term intervals (e.g., 60–180 seconds).
- **Decision Optimization:** Scalarizes multiple objectives with priority hierarchy (safety > efficiency > accessibility).
- **Policy Explanation Module:** Produces interpretable justifications for operator review and compliance assurance.

c. **Output:** Candidate actions (e.g., adjust gate throughput, modulate PSD opening) are forwarded to the *Runtime Safety and Cyber Assurance Layer* for validation.

6. Runtime Safety and Cyber Assurance Layer

a. Function: Implements the terminal safety and cybersecurity gate, ensuring that only verified, compliant, and trustworthy actions are executed.

b. Key Mechanisms:

- Formal Safety Shields: Enforce invariant checks ensuring that physical and logical safety conditions are never violated (e.g., PSD opens only when train is stationary and aligned).
- Drift and Spoof Detection: Monitors sensor reliability, communication integrity, and data distribution shifts.
- Command Verification and Signing: Authenticates and cryptographically signs all control messages.
- Fail-Safe Operation: Reverts to deterministic, safe fallback policies under degraded or uncertain conditions.

d. Output: Approved and signed commands are transmitted to the Actuation System; event logs and anomaly alerts are relayed to the AI Core and Human-Over-the-Loop Console.

7. Actuation System

Function:

Executes verified control commands on physical infrastructure components of the railway platform.

Controlled Subsystems include:

- Platform Screen Doors (PSD): Synchronize open/close cycles with train positioning.
- Signage and Display Boards: Dynamically update guidance, warnings, and evacuation messages.
- HVAC Systems: Adjust airflow, temperature, and illumination in response to occupancy.
- Escalators and Elevators: Regulate direction, velocity, and dispatch priority.

- Gates and Service Robots: Control entry metering and assist passengers requiring support.
- Train Coordination Hooks: Interface with Automatic Train Supervision (ATS) systems for synchronized holds and releases.

Feedback:

Execution telemetry and actuator states are returned to the *State Estimation Unit* for closed-loop correction and continuous learning.

8. Human-Over-the-Loop Console

a. **Function:**

Provides human oversight, ethical governance, and interactive supervision of automated decisions.

b. **Features:**

- **Explainable Interface:** Presents AI reasoning chains, risk levels, and confidence metrics.
- **Approval Workflow:** Allows operators to approve, defer, or override AI-proposed actions.
- **Simulation Preview:** Enables "what-if" validation within the digital-twin environment before live deployment.
- **Training Feedback Loop:** Incorporates operator corrections to refine future AI Core behavior.

9. Interconnections and Information Flow

- **Upstream Flow:** Sensors → Fusion → Estimation → AI Core → Policy → Safety → Actuation
- **Downstream Feedback:** Actuation → Estimation → AI Core → Human Console (closed-loop learning)
- **Human Oversight:** Continuous bi-directional interaction between the Human Console, Policy Layer, and Actuation System ensures transparency and accountability.

10. Edge–Cloud Synchronization

The system operates in a hybrid edge–cloud paradigm:

- **Edge Tier:** Executes time-critical perception, control, and safety tasks near the platform for sub-second response.
- **Cloud Tier:** Performs high-fidelity simulations, model retraining, and long-term digital-twin analytics.
- **Synchronization Link:** Maintains a secure, encrypted data channel for logs, learning data, and version updates.

DETAILED DESCRIPTION OF INVENTION

The invention provides an intelligent station-management framework that overcomes the operational limitations of human-dependent and rule-based control systems presently deployed at railway platforms. The ASI-RSP is conceived as a self-governing cognitive infrastructure that integrates perception, prediction, optimization, and actuation into a single closed-loop mechanism. It continuously senses environmental data, interprets complex passenger and train dynamics, anticipates emerging situations, and executes optimized control responses in real time.

Conventional station-management architectures rely upon isolated subsystems such as CCTV surveillance, platform screen-door (PSD) control, train-schedule monitoring, and public-address units. Each operates on local logic and requires human coordination for event correlation and decision implementation. This fragmentation introduces latency, inconsistent responses, and error propagation during high-density passenger flow or emergency circumstances. Current AI-based solutions offer localized analytics—such as obstacle detection or passenger counting but lack unified decision authority, cross-domain prediction, and safety-verified autonomy.

The ASI-RSP introduces a superintelligent orchestration layer that assimilates all data and control flows under one adaptive cognitive controller. The controller's intelligence hierarchy performs end-to-end reasoning, encompassing sensory fusion, predictive modelling, optimization under multi-objective constraints, and deterministic actuation. Its continuously synchronized digital twin serves as the computational mirror of the real platform, representing passengers, trains, mechanical devices, and environmental states with high temporal fidelity.

The invention thereby establishes an autonomous, self-verifying station platform, capable of sustaining safe, efficient, and responsive operation without manual dependency while remaining fully compliant with safety governance standards.

Architecture of the ASI:

The ASI Controller constitutes the cognitive nucleus of the system. It is implemented as a layered intelligence stack comprising perception, prediction, optimization, and actuation hierarchies, each reinforced with internal verification and redundancy.

1. **Perception Sub-Layer Architecture**:

The perception sub-layer performs multimodal sensing and environmental assimilation. Inputs are obtained from CCTV cameras (visible, infrared, and thermal), radar/lidar units, PSD encoders, acoustic microphones, entry/exit gate sensors, and train-borne transceivers. Data from these heterogeneous sources is processed through local edge computing modules performing frame differencing, object recognition, spectral filtering, and temporal correlation.

The perception algorithms execute sensor fusion by aligning spatial coordinates, timestamp synchronization, and feature correlation across modalities. For instance, visual passenger clusters detected by cameras are cross-validated with radar density maps and thermal contours to form unified occupancy estimations. The resultant fused data stream updates the digital twin at a refresh frequency between 10 Hz and 50 Hz depending on sensor bandwidth.

2. **Predictive Modelling Framework**:

The prediction layer operates atop the perception layer to anticipate future states of the platform environment. It employs deep temporal-spatial learning architectures, including graph neural networks, recurrent transformer models, and probabilistic causal frameworks. These models forecast short-term events such as passenger congestion, anomalous movement near PSD lines, or train alignment deviations.

Predictive modelling extends beyond immediate forecasting by maintaining context-aware time horizons—for example, a five-minute forecast of crowd inflow based on ticketing-tap sequences and historical ridership patterns. Such predictive capability enables pre-emptive control actions rather than reactive measures, thereby improving both safety and throughput.

3. **Optimization Layer and Decision Logic**:

The optimization layer serves as the executive reasoning unit. It applies multi-objective mathematical optimization techniques to determine the most suitable action set balancing safety, passenger comfort, service efficiency, and energy utilization. The controller evaluates numerous candidate policies generated through reinforcement-learning agents trained under constraint conditions.

The optimization process is governed by a dynamic reward function that weights parameters according to contextual relevance—such as increasing safety dominance during emergency alerts or energy efficiency during off-peak hours. Each computed decision undergoes internal validation through formal safety-logic evaluators before transmission to actuation interfaces.

4. **Actuation and Execution Mechanism**:

The actuation layer translates the optimized decisions into precise commands for physical and digital subsystems. Actuation covers PSD control, lighting regulation, ventilation, alarm activation and passenger information display updates. Control signals are transmitted through deterministic low-latency channels ensuring sub-100 ms response time for safety-critical operations.

Each actuation instance is accompanied by a feedback acknowledgment from the device interface confirming command execution and state update. These feedbacks are immediately assimilated into the digital twin, closing the real-time perception–decision–actuation loop.

5. **Digital Twin and Internal Representation**:

At the core of the ASI controller lies the continuously evolving digital twin—a comprehensive computational model representing all entities within the station environment. Each entity (train, passenger cluster, PSD segment, environmental zone) maintains state variables such as position, velocity, temperature, and occupancy density.

The digital twin operates as a dynamic graph in which nodes correspond to physical entities and edges represent functional or spatial relationships. Real-time updates ensure that the ASI's perception of the platform remains synchronized to physical reality within millisecond resolution. This allows the controller to simulate possible outcomes before enacting them, thus preventing unsafe or inefficient actions.

6. **Verification and Self-Integrity Mechanisms:**

Given the safety-critical nature of railway operations, the ASI controller employs formal verification and integrity-monitoring routines. Each decision policy is cross-checked against temporal-logic safety constraints prior to deployment. Watchdog processes continuously evaluate controller health, computational latency, and anomaly indicators. In case of detected inconsistency, the controller transitions to a verified fallback state ensuring continuity of essential safety functions without uncontrolled behaviour.

Architecture of the System

1. **Hierarchical Composition:**

The ASI-RSP is realized as a distributed hierarchical network of edge, intermediate, and central layers. This configuration enhances reliability, reduces data congestion, and supports modular scalability across platforms of varying sizes.

- Edge Sensor Arrays perform primary data acquisition and low-level preprocessing.
- Edge Compute Units handle local inference tasks such as object detection, background subtraction, and acoustic classification.
- Station Gateway aggregates edge data, applies timestamp harmonization, and routes synchronized information to the central ASI controller.
- Central ASI Controller executes advanced prediction and optimization algorithms.
- Actuation Interfaces relay verified commands to controlled devices through deterministic protocols.
- Human Oversight Console provides supervisory visualization, manual control override, and audit logging.
- Data Security Layer ensures encrypted communication, anonymization, and identity management.

2. **Communication Infrastructure:**

All components are interconnected through time-sensitive networking (TSN) Ethernet or equivalent deterministic communication buses. The network architecture supports guaranteed latency and jitter bounds essential for safety compliance. Redundant communication links provide fault tolerance, while message-authentication codes protect against spoofing or injection attacks.

3. **Edge Computing and Local Autonomy:**

To minimize dependency on central bandwidth, each edge compute node possesses limited autonomy. It can locally detect hazards, such as obstruction of a PSD sensor and initiate immediate corrective action (for example, halting door closure) while simultaneously notifying the central controller. This distributed intelligence ensures micro-second response to localized events without waiting for high-level decision cycles.

4. **Redundancy and Failover Design:**

The system architecture incorporates redundant nodes for the ASI controller and critical gateways. In the event of hardware failure or software hang, a standby controller assumes control within two decision cycles. Data replication between nodes is performed through journaled transaction logs, maintaining consistent system state across the redundancy cluster.

5. **Integration with Existing Railway Subsystems:**

The ASI-RSP is designed for seamless integration with legacy station systems through standardized APIs (REST, OPC-UA, MQTT). It can interface with timetable servers, ticketing databases, and signaling controllers, thereby forming an interoperable operational ecosystem rather than a replacement infrastructure.

Operational Functioning

1. **Continuous Cognitive Loop**:

The ASI-RSP operates through a continuously executing cognitive loop that integrates perception, reasoning, and control. This closed-loop cycle allows the system to interpret sensory inputs, simulate potential outcomes, and actuate corresponding responses in real time. The process runs perpetually, with each iteration updating the internal digital twin and refining predictive accuracy.

During normal operation, sensor data flows into the ASI controller's perception sub-layer. The data is processed into unified state representations that form the foundation for predictive forecasting. The ASI then evaluates multiple possible response policies through its optimization layer, selecting the one that maximizes the cumulative safety and efficiency score under the system's objective constraints. The chosen actuation plan is dispatched to the control interfaces, and the resultant system states are fed back into the digital twin for continuous self-calibration.

2. **Perception and Data Ingestion**:

The perception phase begins with data acquisition from all sensors distributed throughout the station environment. These include CCTV cameras, thermal and infrared sensors, radar and lidar modules, platform screen door (PSD) encoders, acoustic microphones, and entry-exit gate sensors. Each sensor generates heterogeneous data formats—video frames, distance point clouds, audio spectrograms, and mechanical status parameters—which are preprocessed at the edge.

Noise reduction and temporal alignment algorithms remove redundant frames, synchronize timestamps, and normalize data quality. Edge modules perform preliminary detection of objects and anomalies to reduce bandwidth consumption. For example, only motion-flagged video segments or threshold-exceeding thermal zones are transmitted to the ASI controller, ensuring efficient and scalable data flow.

3. **Event Prediction and Risk Classification**:

After ingestion, the ASI controller executes its predictive inference phase. The prediction layer examines the evolving states of passengers, trains, and mechanical devices to anticipate events that could affect safety or service quality. This includes detection of crowd surges, unauthorized track incursions, abnormal posture indicative of a fallen passenger, train alignment discrepancies, or suspicious static objects left unattended.

Each forecasted event is characterized by a confidence score and a predicted time-to-occurrence metric. The ASI maintains a rolling buffer of predicted events over short-, medium-, and long-term horizons, allowing parallel management of immediate risks and future resource allocation. Predictive modeling is continuously refined using reinforcement and transfer learning, ensuring adaptability to station-specific behavioural patterns and environmental variability.

4. **Decision Synthesis and Multi-Objective Optimization**:

Upon identifying a set of potential events, the optimization layer generates and evaluates a corresponding set of remedial or preventive actions. These actions may include regulating platform entry gates, altering passenger flow via public-address messages, dynamically adjusting PSD open/close timings, or modifying lighting and ventilation conditions to disperse congestion.

Each possible action is tested through the ASI's internal simulation engine, which operates on the digital twin. The engine forecasts the impact of each action on key objectives such as safety assurance, passenger throughput, waiting time reduction, and energy consumption. A multi-objective optimization function then selects the action sequence that yields the globally optimal trade-off under current operational constraints.

5. **Actuation, Verification and Feedback**:

Once the optimal action is determined, it is transmitted to the relevant actuation subsystems through verified low-latency channels. Actuators respond immediately by executing mechanical or digital commands—for example, adjusting platform screen door alignment, activating ventilation blowers, or updating visual signage.

Each actuation cycle includes a verification handshake mechanism wherein the actuator confirms successful execution to the ASI controller. In the absence of acknowledgment or if a mismatch is detected between the commanded and observed state, the controller triggers a retry or fallback command sequence. This guarantees deterministic and fail-safe execution even under transient network or hardware faults.

The results of all actuations are incorporated back into the digital twin, enabling the ASI to measure its policy's effectiveness and recalibrate predictive weights in subsequent cycles. This constant refinement ensures that the system's decision-making efficiency and safety assurance improve over time.

6. **Adaptive and Contextual Learning**

The ASI controller employs context-sensitive learning to adapt its internal models based on evolving operational patterns. For instance, during high-traffic hours, it learns crowd distribution patterns specific to the station's geometry and adjusts evacuation routing priorities accordingly. Similarly, during off-peak conditions, it recognizes underutilized resource zones and optimizes energy usage through selective subsystem deactivation.

This adaptive capability transforms the ASI-RSP from a static automation system into a self-evolving cognitive infrastructure, continuously optimizing itself to the dynamic and heterogeneous nature of real-world railway environments.

Safety and Compliance

1. **Safety-First Design Philosophy**:

Safety forms the foundation of the ASI-RSP's architecture. Every design element from perception algorithms to hardware redundancy is developed to ensure that the system operates within formally verified safety envelopes. The ASI controller never executes any control decision that has not been evaluated against its safety verification constraints.

2. **Formal Verification of Control Logic**:

The invention incorporates a formally verified control stack, wherein each policy generated by the optimization layer is validated through mathematical safety models using temporal logic specifications. These specifications define non-violable rules, such as minimum train–platform clearance distance, maximum passenger density thresholds, or fail-safe PSD closure timing. Any decision violating these rules is automatically discarded, and the system defaults to a predefined safe mode.

Formal verification ensures provable guarantees that certain hazardous states are unachievable under the controller's operational logic, even in the presence of uncertain or incomplete sensory data.

3. **Fail-Safe and Fallback Operations**

To handle sensor, communication, or computational failures, the ASI-RSP employs multiple fallback strategies. In the event of network disconnection, edge nodes assume localized safety control, maintaining PSD lock integrity and sustaining critical alarm functions. In case of hardware fault or power loss at the central ASI controller, redundant backup controllers automatically assume operational control through a warm-standby mechanism with minimal delay.

Fallback operation modes are pre-certified under safety standards, ensuring uninterrupted passenger protection. During degraded operation, the system prioritizes safety-critical functions such as obstruction detection, emergency lighting, and evacuation path indication over non-critical energy optimization or data-logging functions.

4. **Human Oversight and Override**

While the ASI-RSP functions autonomously, the system incorporates human-in-the-loop oversight for regulatory and operational assurance. A secure human console displays real-time system states, predicted risks, and decision justifications. Authorized personnel may override ASI actions under verified authentication protocols. Each human intervention is logged with timestamp, identity, and event context for auditability.

This design preserves accountability and operational transparency, aligning with both ethical AI principles and railway governance requirements.

5. **Standards and Regulatory Compliance**

The system is compliant with major railway and industrial standards, including IEC 62290 for urban guided transport management and EN 50126/50128/50129 for Reliability, Availability, Maintainability and Safety (RAMS). Hardware and software components are designed to meet SIL (Safety Integrity Level) classifications appropriate for their function.

Additionally, cybersecurity practices conform to ISO/IEC 27001 and railway-specific cybersecurity frameworks, protecting the platform infrastructure from unauthorized access and data breaches.

Privacy and Data Protect

Given the extensive use of sensors and data analytics, the invention implements a privacy-by-design architecture ensuring that no identifiable personal information is retained or processed beyond operational necessity. The ASI-RSP does not store or use individual biometric features; instead, it abstracts all passenger data into anonymized entities within the digital twin.

Edge preprocessing modules perform real-time anonymization, such as facial blurring or feature vector abstraction, before data leaves the local sensor domain. Consequently, the central controller receives only de-identified and abstracted environmental states, preserving both functionality and privacy.

All communication between sensors, gateways, and the ASI controller is encrypted using asymmetric encryption (RSA-4096 or post-quantum equivalents). Data in transit and at rest is protected through integrity verification and hashing mechanisms. Access control policies ensure that only authenticated processes can initiate or retrieve data streams.

Operational data is retained for limited durations typically not exceeding 72 hours after which it is automatically purged unless required for audit or investigation. Logs are cryptographically signed to prevent tampering or retroactive modification.

The system design aligns with national data protection frameworks and global privacy standards, including the Information Technology (Reasonable Security Practices and Procedures) Rules, 2011 and GDPR principles where applicable. Since all data representations in the digital twin are non-identifiable abstractions, the system inherently eliminates the risk of personal data misuse.

The ASI-RSP follows an ethical AI governance model. Decision transparency is maintained through explainable-AI interfaces that allow auditors to trace each actuation decision back to its causal prediction and data inputs. This facilitates external verification of fairness and accountability, particularly for public-sector transportation deployments.

By integrating privacy, transparency, and accountability into its foundational design, the invention ensures that technological advancement does not compromise passenger rights or institutional responsibility.

Maintenance, Energy, and Learning Functions

The ASI-RSP incorporates a predictive maintenance subsystem that continuously monitors the operational health of critical components such as Platform Screen Doors (PSDs), escalators, lighting circuits, HVAC units, sensors, and edge computing nodes. Sensor readings—including actuator currents, cycle counts, vibration signatures, and thermal profiles—are processed in real time to identify degradation trends.

Deviations from nominal operational profiles trigger maintenance advisories or pre-emptive interventions. For example, an approaching wear threshold in a PSD actuator prompts micro-downtime scheduling in low-traffic intervals, ensuring uninterrupted passenger service while preventing unplanned failures. All maintenance actions are logged and timestamped in the system's tamper-evident Command Journal, ensuring traceability and audit compliance.

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Energy Optimization - Energy management is integrated within the ASI-RSP's operational planning logic. Lighting, HVAC, and auxiliary power are dynamically adjusted based on real-time occupancy, environmental conditions, and safety requirements. Multi-objective optimization algorithms balance passenger comfort, visibility, and energy efficiency, ensuring compliance with pre-defined energy budgets without compromising safety.

Edge controllers locally implement rapid adjustments (e.g., dimming lights in low-occupancy zones), while the ASI Core periodically refines setpoints through higher-order optimization using aggregated station-wide data. Predictive modeling enables anticipation of peak demand periods, allowing preemptive load management and sustainable energy utilization.

Federated and Privacy-Preserving Learning - The ASI-RSP employs federated learning frameworks to update perception and predictive models without centralizing raw data. Edge nodes compute local model updates using anonymized and redacted sensor inputs; only differential gradients are transmitted to the central ASI Core.

Before deployment, aggregated updates undergo sandboxed simulation and formal safety verification to ensure compliance with safety invariants. Models introducing unsafe behaviors or exceeding bounded confidence deviations (e.g., >2 % deviation from certified safety envelopes) are rejected. Approved models are cryptographically signed, versioned, and deployed to edge nodes, ensuring integrity and auditability.

Cross-station transfer learning allows the system to adapt rapidly to stations with similar layouts, optimizing dwell-time recovery, signage effectiveness, and crowd routing heuristics while maintaining certified safety margins.

Deployment Architecture and Operational Modes

The ASI-RSP is deployable in a graded autonomy model:

- Advisory Mode: The ASI proposes actions and provides rationale; human operators execute commands.

- Guarded Autonomy Mode: The ASI executes commands within certified safety limits; human supervision and formal safety shields mediate all actions.
- Multi-Platform Orchestration Mode: Coordinated control across adjacent platforms and concourses optimizes passenger distribution, recovery of dwell times, and evacuation management.

During initial deployment, integration with existing Supervisory Control and Data Acquisition (SCADA), Automatic Train Supervision (ATS), and Platform Screen Door (PSD) systems occurs via hybrid interfaces. Safety-critical functions employ deterministic field buses (e.g., PROFINET, EtherCAT) with galvanic isolation and redundant I/O channels to meet SIL-3/4 requirements. Supervisory data exchange occurs through standardized APIs or middleware (OPC UA, REST/gRPC, railway ATS protocols) with timestamp alignment (PTP/GNSS).

Edge-First Reflex Architecture

Latency-critical operations are executed locally at the edge tier (control period ≤200 ms). Functions such as obstruction detection, near-edge passenger alerts, and emergency stop commands operate entirely within the edge layer, independent of Core or Cloud latency.

The ASI Core handles higher-order inference, policy optimization, and risk-aware scheduling. Cloud infrastructure is leveraged for large-scale simulations, policy retraining, and network-wide optimization. Deterministic real-time event buses (RT-Ethernet TSN) connect edge nodes to Core, while secure gRPC or MQTT-QoS 2 channels connect Core to Cloud. All tiers synchronize using IEEE 1588 PTP/GNSS with inter-layer drift < ±5 ms.

During connectivity or hardware loss, control authority defaults to the edge tier, ensuring safety-critical actuation persists. Non-critical Core and Cloud functions degrade gracefully to advisory or logging modes. The system dynamically narrows actuation scope, increases signage conservatism, and prompts human verification when uncertainty or data conflicts arise.

Advantages of the present invention:

1. The ASI-RSP provides a hybrid neuro-symbolic intelligence framework capable of multi-objective, causal, and self-verifying reasoning. By maintaining a high-fidelity digital twin updated at 10–50 Hz with sub-200 ms synchronization latency and <5 % estimation uncertainty, the system achieves superhuman decision speed with provable safety guarantees.

2. Formal safety shields enforce non-negotiable invariants, preventing unsafe operations even under human override or system failure. Tamper-evident command journals, runtime assurance frameworks, and verified actuation protocols ensure regulatory compliance, accountability, and traceable safety performance.

3. The ASI-RSP prioritizes equitable passenger experience by optimizing boarding zones, assistive navigation cues (BLE/UWB beacons, haptic notifications), and accessibility-specific actuation (ramps, bridges) without compromising operational efficiency.

4. Federated, privacy-preserving learning enables continuous adaptation and cross-station knowledge transfer while retaining data minimization principles. This design ensures secure, regulator-compliant AI operation across diverse station environments.

5. Predictive maintenance and energy optimization are embedded within operational logic. The system reduces unplanned downtime by ≥50 % and normalizes energy consumption by 10–20 % without violating safety or comfort invariants. Local micro-downtime scheduling, edge-based reflex control, and adaptive HVAC/lighting optimization contribute to resilient and sustainable operations.

6.All ASI decisions are explainable via the Human-over-the-Loop console, which visualizes causal reasoning, predicted risk, and multi-objective trade-offs. This ensures auditable, transparent, and accountable AI governance, aligning with ethical and regulatory standards.

7. In multi-platform deployments, the ASI-RSP orchestrates coherent, risk-bounded operations across multiple concourses, enabling dynamic rebalancing of passenger loads, synchronized evacuations, and coordinated dwell-time recovery, which enhances network-level efficiency and safety.

We claim:

1. An Artificial Superintelligence-Based Railway Station Platform (ASI-RSP) system configured for autonomous, safe, and adaptive management of railway stations, the system comprising:

a. an Artificial Superintelligence (ASI) Controller operatively coupled to a plurality of perception, prediction, optimization, and actuation sub-layers;

b. a Sensor Fusion and Perception Sub-Layer configured to receive multimodal data from visual, radar, lidar, acoustic, mechanical, and environmental sensors distributed across the railway platform, process said data through edge computing modules, and generate a unified situational representation;

c. a Predictive Modelling Framework configured to forecast future operational states of the platform environment using temporal-spatial deep learning, causal inference, and graph-based neural architectures;

d. an Optimization and Decision Logic Layer configured to compute control policies through multi-objective optimization and reinforcement learning under safety and operational constraints;

e. an Actuation Layer configured to execute verified control actions by transmitting deterministic commands to physical and digital subsystems including platform screen doors (PSDs), lighting, HVAC systems, escalators, alarm systems, and passenger information displays;

f. a Digital Twin Module maintained by the ASI Controller and configured to continuously replicate real-time station conditions, including dynamic passenger and train states;

g. a Human-Over-the-Loop Console configured to visualize system decisions, allow human supervision, override, or modification of AI policies, and record operator interactions for auditability; and

h. a Verification and Integrity Mechanism configured to validate all decisions against formal safety logic constraints and initiate fallback control states in case of anomalies or failure;

wherein the ASI Controller performs continuous closed-loop cognition comprising sensing, prediction, optimization, actuation, and feedback to maintain safe, efficient, and autonomous station operation.

2. The system as claimed in claim 1, wherein the Sensor Fusion Sub-Layer performs spatial and temporal alignment across heterogeneous data modalities and fuses sensor outputs to generate occupancy estimations with refresh frequencies between 10 Hz and 50 Hz.
3. The system as claimed in claim 1, wherein the Predictive Modelling Framework employs graph neural networks, recurrent transformer models, and probabilistic causal inference to anticipate passenger congestion, train misalignment, or abnormal motion patterns.
4. The system as claimed in claim 1, wherein the Optimization Layer employs a reinforcement-learning policy generator trained under multi-objective reward functions balancing parameters of safety, energy efficiency, passenger comfort, and throughput.
5. The system as claimed in claim 1, wherein each control decision is validated through formal safety verification based on temporal logic specifications defining non-violable operational constraints including minimum clearance, maximum occupancy thresholds, and fail-safe actuation timing.
6. The system as claimed in claim 1, wherein the Digital Twin comprises a dynamic graph representation of station entities, each node corresponding to a physical asset or passenger cluster and each edge representing spatial or functional relationships, updated within a sub-200 ms synchronization latency.
7. The system as claimed in claim 1, wherein the Actuation Layer communicates through deterministic, low-latency channels achieving response times below 100 ms for safety-critical operations and implements feedback acknowledgment from each controlled device.
8. The system as claimed in claim 1, wherein the Verification Mechanism includes watchdog processes configured to monitor controller health,

latency deviation, and anomaly indicators, and trigger a verified fallback mode upon detecting inconsistencies.

9. The system as claimed in claim 1, wherein the ASI-RSP is realized as a hierarchical network of distributed edge, intermediate, and central computational layers connected through time-sensitive networking (TSN) Ethernet or equivalent deterministic communication protocols.
10. The system as claimed in claim 9, wherein edge computing nodes are configured with local autonomy to execute hazard-mitigation actions, including halting platform door closure or initiating emergency alerts, independent of the central controller.
11. The system as claimed in claim 1, wherein redundancy is provided by standby ASI controllers and gateways configured to assume operational control within two decision cycles in the event of hardware or communication failure.
12. The system as claimed in claim 1, further comprising integration interfaces using standardized protocols including REST, OPC-UA, or MQTT to interoperate with legacy station systems such as timetable servers, ticketing databases, and signalling controllers.
13. The system as claimed in claim 1, wherein the ASI Controller employs federated and privacy-preserving learning frameworks to update predictive and perception models based on anonymized edge-node gradients without centralizing raw sensory data.
14. The system as claimed in claim 13, wherein federated model updates are subjected to sandboxed simulation and safety verification prior to deployment, and models failing safety-envelope criteria are automatically rejected.
15. The system as claimed in claim 1, wherein the Human-Over-the-Loop Console provides explainable-AI interfaces enabling visualization of causal reasoning chains, predicted risks, and objective trade-offs for transparency and accountability.
16. The system as claimed in claim 1, wherein the ASI Controller supports graded autonomy levels comprising:

a. *Advisory Mode* providing decision recommendations to human operators;
b. *Guarded Autonomy Mode* executing certified safe actions under human supervision; and
c. *Multi-Platform Orchestration Mode* coordinating control actions across multiple platforms and concourses.

17. The system as claimed in claim 1, wherein the ASI-RSP includes a predictive maintenance subsystem configured to monitor actuator currents, vibration spectra, and cycle counts to forecast equipment wear and schedule pre-emptive service during low-traffic intervals.
18. The system as claimed in claim 1, wherein energy optimization is achieved by dynamically regulating lighting, HVAC, and auxiliary loads based on occupancy and environmental data through multi-objective optimization of comfort and energy efficiency.
19. The system as claimed in claim 1, wherein all communication and data storage operations are protected through asymmetric encryption, integrity hashing, and access control policies conforming to national and international data protection standards.
20. The system as claimed in claim 1, wherein the ASI-RSP provides an explainable, self-verifying, and privacy-preserving framework achieving superhuman decision speed with sub-5 % estimation uncertainty and provable compliance with railway safety standards IEC 62290 and EN 50126/50128/50129.
21. 21. A method for autonomous and adaptive management of a railway station platform using an Artificial Superintelligence-Based Railway Station Platform (ASI-RSP) system as claimed in any of claims 1–20, the method comprising the steps of:

a. acquiring multimodal sensory data from distributed sensing units including visual, acoustic, lidar, radar, and environmental sensors installed across the platform;
b. preprocessing and anonymizing said sensory data through edge analytics units configured to perform noise suppression, privacy redaction, and temporal alignment;

c. performing sensor fusion to generate a unified situational awareness model representing real-time crowd density, passenger trajectories, and environmental conditions;

d. updating a digital twin of the railway platform environment based on said fused data to reflect real-time physical states;

e. performing predictive simulation and risk estimation within the digital twin using machine learning, causal inference, and reinforcement learning to forecast congestion, anomalies, or potential safety hazards;

f. generating one or more control policies through an optimization engine configured to evaluate trade-offs between multiple objectives including safety, throughput, energy efficiency, and passenger comfort;

g. transmitting the generated control policies to a Human-Over-the-Loop Console for visual review and approval by an authorized operator;

h. upon human validation, executing said policies through an Actuation Layer to control physical subsystems including platform screen doors, escalators, gates, HVAC, lighting, and signage; and

i. continuously updating system behavior based on feedback from actuators and sensor data, enabling adaptive learning and self-calibration of the ASI-RSP.

22. The method as claimed in claim 21, wherein the step of sensor fusion includes probabilistic Bayesian fusion, Kalman filtering, and graph-based temporal aggregation for integrating heterogeneous sensor modalities.

23. The method as claimed in claim 21, wherein the predictive simulation employs hybrid digital twin modeling combining data-driven neural inference with rule-based physical simulation for dynamic passenger behavior modeling.

24. The method as claimed in claim 21, wherein control policy generation is performed through a model-predictive control (MPC) process configured to solve a constrained optimization problem that maximizes safety and efficiency objectives under real-time operational constraints.

25. The method as claimed in claim 21, wherein the reinforcement learning module employs reward shaping functions incorporating weighted parameters for safety (w_1), efficiency (w_2), and sustainability (w_3).
26. The method as claimed in claim 21, wherein human operator inputs and overrides are recorded and supplied as feedback data for continuous fine-tuning of the ASI-RSP models via supervised and reinforcement learning.
27. The method as claimed in claim 21, wherein the digital twin environment performs simulation validation of each policy prior to execution, comparing projected and actual outcomes to maintain verified safety envelopes.
28. The method as claimed in claim 21, wherein actuator feedback includes real-time operational confirmation, error detection, and performance metrics transmitted to the ASI Controller for policy recalibration.
29. The method as claimed in claim 21, wherein the ASI-RSP autonomously transitions between multiple operational states including:

a. Normal mode – full operation with human supervision;
b. Advisory mode – AI provides decision recommendations without direct actuation; and
c. Emergency mode – safety-verified autonomous response during critical events such as overcrowding, fire, or mechanical failure.

30. The method as claimed in claim 21, wherein feedback loops enable adaptive learning wherein deviations between predicted and actual system responses are used to update predictive and optimization models through online reinforcement learning.
31. The method as claimed in claim 21, wherein the ASI-RSP employs federated learning across distributed station nodes, each node transmitting encrypted model updates without sharing raw passenger data, thereby ensuring data privacy and regulatory compliance.
32. The method as claimed in claim 21, wherein the energy management subsystem dynamically modulates non-critical loads, including lighting and HVAC, based on predicted passenger occupancy and environmental comfort parameters.

33. The method as claimed in claim 21, wherein all communications between modules employ cryptographic validation, integrity checks, and timestamped logging for cyber-physical security assurance.
34. The method as claimed in claim 21, wherein the ASI-RSP maintains a continuously verified self-diagnostic framework detecting sensor drift, communication latency, and policy anomalies and initiating fallback or manual intervention protocols upon detection.
35. The method as claimed in claim 21, wherein the ASI-RSP provides explainable-AI outputs by generating natural-language and graphical justifications for each decision to facilitate transparency and regulatory compliance.
36. The method as claimed in claim 21, wherein the ASI-RSP coordinates inter-platform synchronization by managing train dwell times, crowd distribution, and sequential boarding logic across multiple stations within a transit network.
37. The method as claimed in claim 21, wherein predictive maintenance analytics are applied to actuation devices by monitoring vibration, electrical current, and cycle duration data to forecast potential mechanical degradation and schedule proactive service.
38. The method as claimed in claim 21, wherein safety integrity verification of all AI-driven control policies is performed in compliance with railway automation standards including IEC 62290, EN 50126, EN 50128, and EN 50129.
39. The method as claimed in claim 21, wherein the system achieves latency-optimized control cycles within a decision time of less than 200 milliseconds while maintaining fail-safe redundancy through dual-controller operation.
40. The method as claimed in claim 21, wherein the ASI-RSP autonomously manages railway station operations through continuous perception, cognition, optimization, actuation, and verification cycles to maintain superhuman reliability, operational efficiency, and passenger safety.

Dated this 2nd day of November 2025

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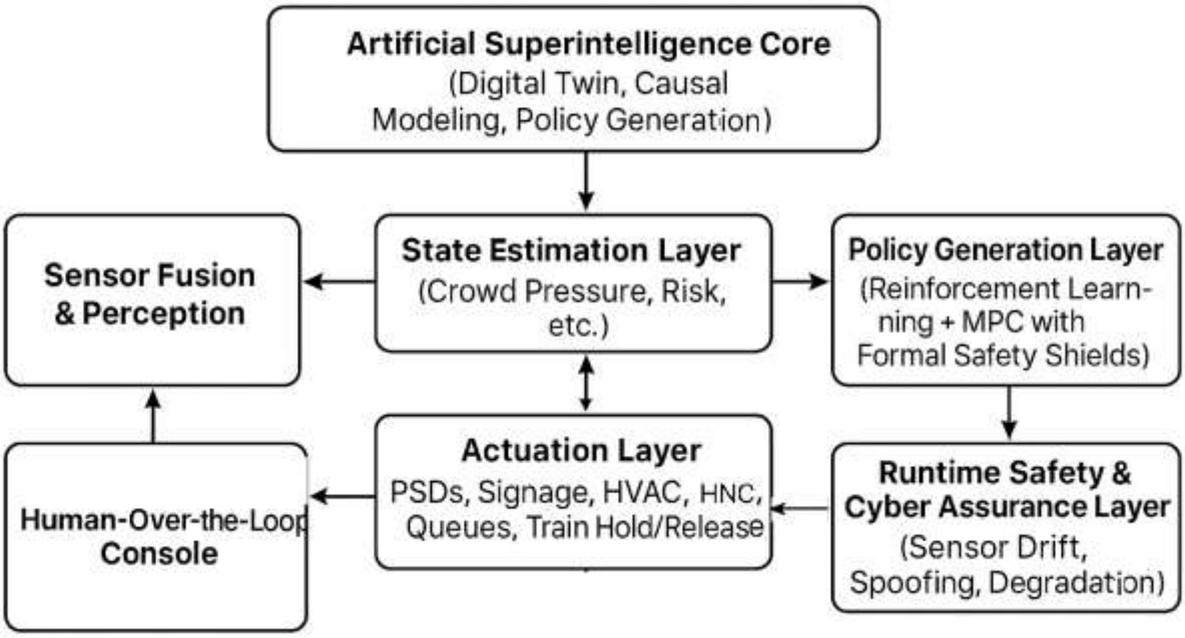
APPLICATION NO.____________

ABSTRACT

ARTIFICIAL SUPERINTELLIGENCE-BASED RAILWAY STATION PLATFORM

The present invention relates to an Artificial Superintelligence-Based Railway Station Platform (ASI-RSP) system and method for autonomous, adaptive, and safe management of railway stations. The system integrates multimodal sensing, digital twin simulation, and reinforcement-learning-based decision optimization to monitor, predict, and control station operations in real time. Sensor fusion modules collect visual, acoustic, lidar, radar, and environmental data to generate a unified situational map. An Artificial Superintelligence Core performs predictive modeling, causal reasoning, and policy generation, while a Human-Over-the-Loop Console provides supervised review and explainable decision support. The Actuation Layer executes approved control actions for platform screen doors, gates, escalators, HVAC, and signage, with continuous feedback ensuring adaptive recalibration. The invention enables privacy-preserving analytics, predictive maintenance, and energy optimization while maintaining compliance with safety and ethical standards. The ASI-RSP thereby achieves autonomous yet human-supervised station operation with enhanced safety, efficiency, and sustainability.

Fig 2



Detailed Flowchart

Figure 1

Sudarshana

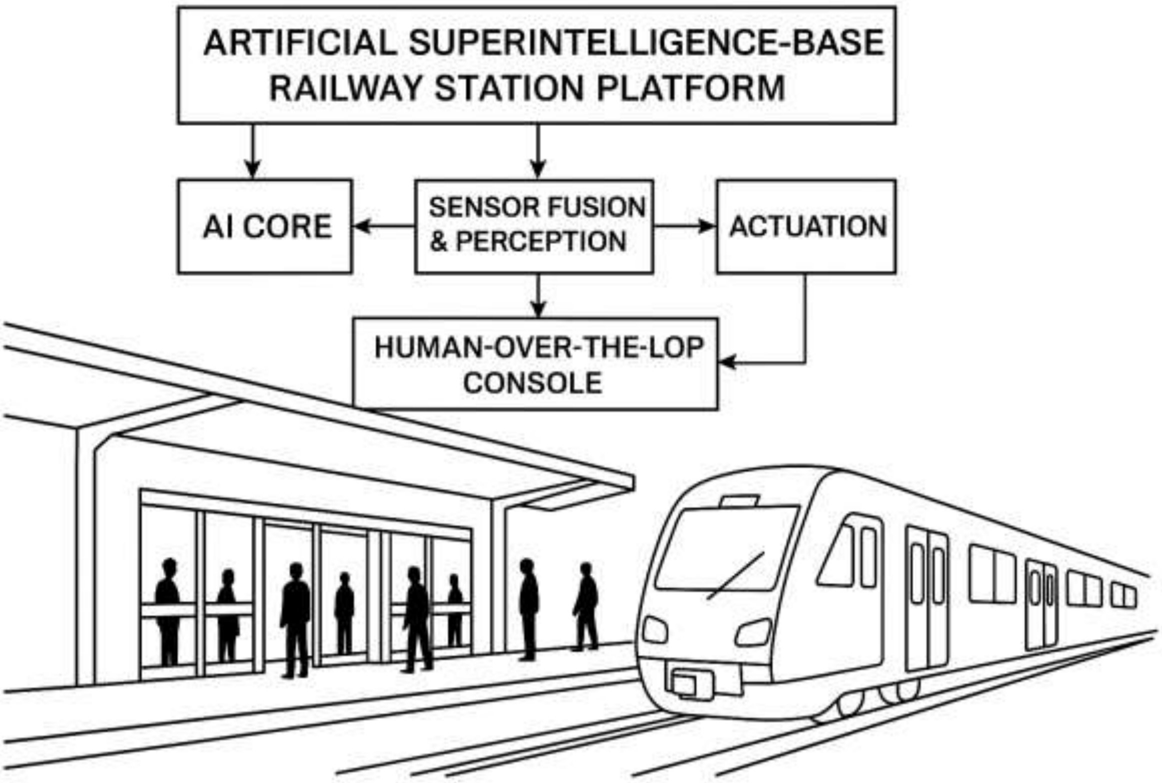
Sudarshana Bandyopadhyay
Regn No.: IN/PA 2802
Agent for the Applicants

Applicant Name: SRJX RESEARCH AND INNOVATION LAB LLP

Total No. of Sheets: 3

Appl No. -

Figure 2 of 3



Detailed Architecture

Figure 2

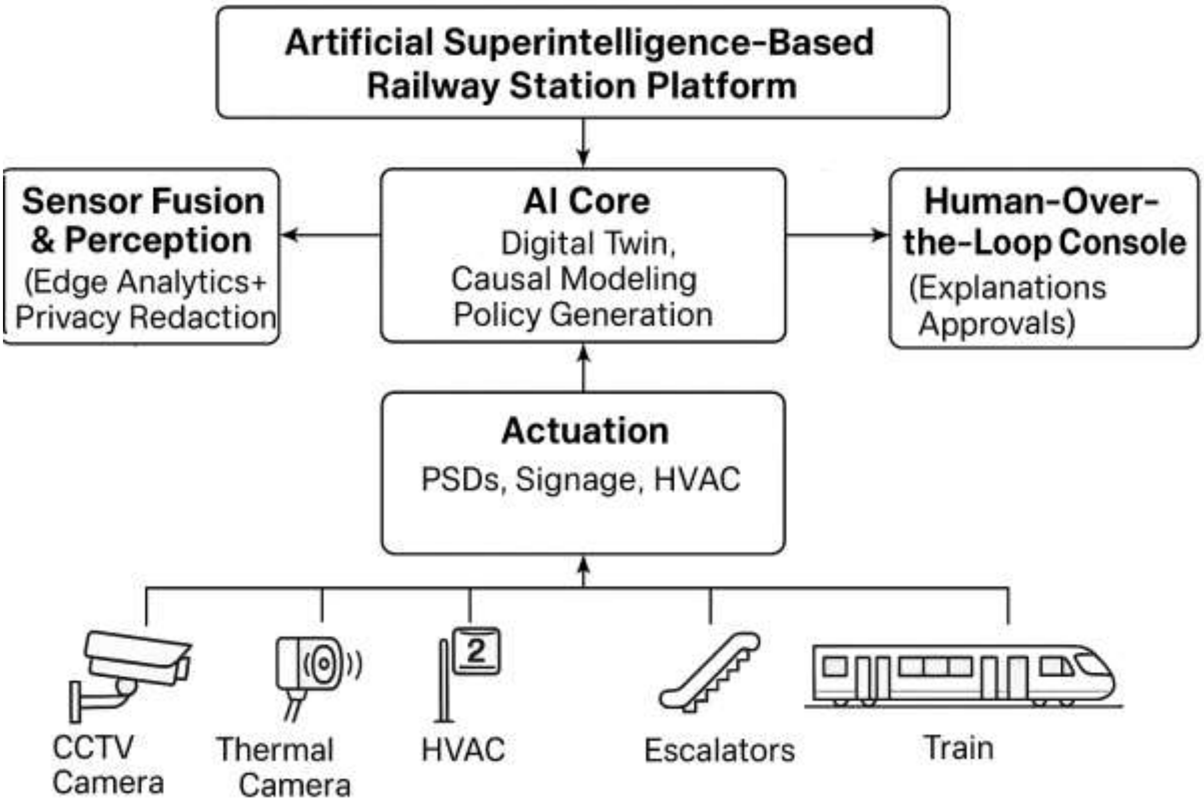
Sudarshana

Sudarshana Bandyopadhyay
Regn No.: IN/PA 2802
Agent for the Applicants

Applicant Name: SRJX RESEARCH AND INNOVATION LAB LLP

Total No. of Sheets: 3

Appl No. -



Device Diagram

Figure 3

Sudarshana

Sudarshana Bandyopadhyay
Regn No.: IN/PA 2802
Agent for the Applicants

FORM 5
THE PATENTS ACT, 1970
(39 of 1970)
&
THE PATENTS RULES, 2003

Declaration as to Inventorship
[*See* section 10(6) and rule 13(6)]

1. **NAME OF APPLICANT**: SRJX RESEARCH AND INNOVATION LAB LLP,

hereby declare that the true and first inventor(s) of the invention disclosed in the complete specification filed in pursuance of our application numbered ____________________ dated 2 November 2025 are:

2. **INVENTORS:**

I. a) Name: **DR SOUMYA RANJAN JENA**
b) Nationality: An Indian National
c) Address: Plot No - 3E/474, Sector-9, CDA, Post- Markat Nagar,
Cuttack-753014, Odisha, India

Dated this 2nd day of November 2025

Sudarshana

Name of the signatory:

Dated this 2nd day of November 2025

Sudarshana Bandyopadhyay
Regn No.: IN/PA 2802
Agent for the Applicants
Email: bandyopadhyay.sudarshana@gmail.com
Phn No: 9748818235

To,
The Controller of Patents,
The Patent Office
At Kolkata

Signature Not Verified
Digitally Signed.
Name: Sudarshana Bandyopadhyay
Date: 02-Nov-2025 17:13:52
Reason: Patent Efiling

UDYAM REGISTRATION CERTIFICATE

UDYAM REGISTRATION NUMBER	**UDYAM-OD-07-0095836**
NAME OF ENTERPRISE	**SRJX RESEARCH AND INNOVATION LAB LLP**

TYPE OF ENTERPRISE *

SNo.	Classification Year	Enterprise Type	Classification Date
1	2025-26	Micro	16/08/2025

MAJOR ACTIVITY	**SERVICES**
SOCIAL CATEGORY OF ENTREPRENEUR	**GENERAL**

NAME OF UNIT(S)

S.No.	Name of Unit(s)
1	SRJX RESEARCH AND INNOVATION LAB LLP

OFFICAL ADDRESS OF ENTERPRISE

Flat/Door/Block No.	PLOT NO-3E/474	Name of Premises/ Building	SECTOR-9
Village/Town	CDA CUTTACK	Block	NA
Road/Street/Lane	Avinab Bidanasi	City	Cuttack Sadar
State	ODISHA	District	CUTTACK , Pin 753014
Mobile	9090255155	Email:	soumyajena1989@gmail.com

DATE OF INCORPORATION / REGISTRATION OF ENTERPRISE	**05/05/2025**
DATE OF COMMENCEMENT OF PRODUCTION/BUSINESS	**05/05/2025**

NATIONAL INDUSTRY CLASSIFICATION CODE(S)

SNo.	NIC 2 Digit	NIC 4 Digit	NIC 5 Digit	Activity
1	72 - Scientific research and development	7210 - Research and experimental development on natural sciences and engineering	72100 - Research and experimental development on natural sciences and engineering	Services

DATE OF UDYAM REGISTRATION	**16/08/2025**

* **In case of graduation (upward/reverse) of status of an enterprise, the benefit of the Government Schemes will be availed as per the provisions of Notification No. S.O. 2119(E) dated 26.06.2020 issued by the M/o MSME.**

Disclaimer: This is computer generated statement, no signature required. Printed from https://udyamregistration.gov.in & Date of printing - 16/08/2025

Signature Not Verified
Digitally Signed.
Name: Sudarshana Bandyopadhyay
Date: 02-Nov-2025 17:16:43
Reason: Patent Efiling

For any assistance, you may contact:

1. District Industries Centre: CUTTACK (ODISHA)

2. MSME-DFO: CUTTACK (ODISHA)

Udyam Registration Number : UDYAM-OD-07-0095836

Type of Enterprise	MICRO	**Major Activity**	Services
Type of Organisation	Limited Liability Partnership	**Name of Enterprise**	SRJX RESEARCH AND INNOVATION LAB LLP
Owner Name	SRJX RESEARCH AND INNOVATION LAB LLP	**PAN**	AFPFS4480L
Do you have GSTIN	No	**Mobile No.**	9090255155
Email Id	soumyajena1989@gmail.com	**Social Category**	General
Gender	Male	**Specially Abled(DIVYANG)**	No
Date of Incorporation	05/05/2025	**Date of Commencement of Production/Business**	05/05/2025

Bank Details

Bank Name	IFS Code	Bank Account Number
Punjab national bank	PUNB0787800	7878002100002490

Employment Details

Male	Female	Other	Total
3	2	0	5

Investment in Plant and Machinery OR Equipment (in Rs.)

S.No.	Financial Year	Enterprise Type	Written Down Value (WDV)	Exclusion of cost of Pollution Control, Research & Development and Industrial Safety Devices	Net Investment in Plant and Machinery OR Equipment[(A)-(B)]	Total Turnover (A)	Export Turnover (B)	Net Turnover [(A)-(B)]	Is ITR Filled?	ITR Type
1	2023-24	Micro	0.00	0.00	0.00	0.00	0.00	0.00	No	NA

Unit(s) Details

SN	Unit Name	Flat	Building	Village/Town	Block	Road	City	Pin	State	District
1	SRJX RESEARCH AND INNOVATION LAB LLP	PLOT NO-3E/474	SECTOR-9	CDA CUTTACK	NA	Avinab Bidanasi	Cuttack Sadar	753014	ODISHA	CUTTACK

Official address of Enterprise

Flat/Door/Block No.	PLOT NO-3E/474	**Name of Premises/ Building**	SECTOR-9
Village/Town	CDA CUTTACK	**Block**	NA
Road/Street/Lane	Avinab Bidanasi	**City**	Cuttack Sadar
State	ODISHA	**District**	CUTTACK , **Pin :** 753014
Mobile	9090255155	**Email:**	soumyajena1989@gmail.com
Latitude	20.5021859203546	**Longitude:**	85.88860428847029

National Industry Classification Code(S)

SNo.	Nic 2 Digit	Nic 4 Digit	Nic 5 Digit	Activity
1	72 - Scientific research and development	7210 - Research and experimental development on natural sciences and engineering	72100 - Research and experimental development on natural sciences and engineering	Services

Are you interested to get registered on Government e-Market (GeM) Portal	No
Are you interested to get registered on TReDS Portals(one or more)	No
Are you interested to get registered on National Career Service(NCS) Portal	No
Are you interested to get registered on NSIC B2B Portal	No
Are you interested in availing Free .IN Domain and a business email ID	N/A
Are you interested in getting registered on Skill India Digital Portal	No
District Industries Centre	CUTTACK (ODISHA)
MSME-DFO	CUTTACK (ODISHA)
Date of Udyam Registration	16/08/2025
Date of Printing	16/08/2025

IEC Details	
IEC Number	
IEC Status	Inactive
IEC Registration Date	
IEC Modification Date	

“**FORM 1** THE PATENTS ACT 1970 (39 of 1970) and THE PATENTS RULES, 2003 **APPLICATION FOR GRANT OF PATENT** (See section 7, 54 and 135 and sub-rule (1) of rule 20)	(FOR OFFICE USE ONLY)

	Application No.	
	Filing date:	
	Amount of Fee paid:	
	CBR No:	
	Signature:	

1. APPLICANT’S REFERENCE / IDENTIFICATION NO. (AS ALLOTTED BY OFFICE)	

2. TYPE OF APPLICATION [Please tick (✓) at the appropriate category]

Ordinary (✓)		Convention ( )		PCT-NP ( )	
Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )

3A. APPLICANT(S)

Name in Full	Nationality	Country of Residence	Address of the Applicant
SRJX RESEARCH AND INNOVATION LAB LLP	Indian	India	SRJX RESEARCH AND INNOVATION LAB LLP, Plot No - 3E/474, Sector-9, CDA, Post- Markat Nagar, Cuttack-753014, Odisha, India

3B. CATEGORY OF APPLICANT [Please tick (✓) at the appropriate category]

Natural Person ( )	Other than Natural Person		
	Small Entity (✓)	Startup ( )	Others ()

4. INVENTOR(S) [Please tick (✓) at the appropriate category]

Are all the inventor(s) same as the applicant(s) named above?	Yes ( )	No (✓)

If "No", furnish the details of the inventor(s)

Name in Full	Nationality	Country of Residence	Address of the Inventor
DR SOUMYA RANJAN JENA	Indian	India	Plot No - 3E/474, Sector-9, CDA, Post-Markat Nagar, Cuttack-753014, Odisha, India

5. TITLE OF THE INVENTION

ARTIFICIAL SUPERINTELLIGENCE-BASED RAILWAY STATION PLATFORM

6. AUTHORISED REGISTERED PATENT AGENT(S)	IN/PA No.	2802
	Name	Sudarshana Bandyopadhyay
	Mobile No.	9748818235
7. ADDRESS FOR SERVICE OF APPLICANT IN INDIA	Name	**SUDARSHANA BANDYOPADHYAY**
	Postal Address	Ground Floor, S-456, LGF, Greater Kailash – II, New Delhi – 110048, India
	Telephone No.	NA
	Mobile No.	97488 18235
	Fax No.	NA
	E-mail ID	bandyopadhyay.sudarshana@gmail.com

8. IN CASE OF APPLICATION CLAIMING PRIORITY OF APPLICATION FILED IN CONVENTION COUNTRY, PARTICULARS OF CONVENTION APPLICATION

Country	Application Number	Filing date	Name of the applicant	Title of the invention	IPC (as classified in the convention country)
N.A.					

9. IN CASE OF PCT NATIONAL PHASE APPLICATION, PARTICULARS OF INTERNATIONAL APPLICATION FILED UNDER PATENT CO-OPERATION TREATY (PCT)

International application number	International filing date

N.A.	
10. IN CASE OF DIVISIONAL APPLICATION FILED UNDER SECTION 16, PARTICULARS OF ORIGINAL (FIRST) APPLICATION	
Original (first) application No.	Date of filing of original (first) application
N.A.	
11. IN CASE OF PATENT OF ADDITION FILED UNDER SECTION 54, PARTICULARS OF MAIN	
Main application/patent No.	Date of filing of main application
N.A.	N.A.
12. DECLARATIONS	

(i) Declaration by the inventor(s)

(**In case the applicant is an assignee**: the inventor(s) may sign herein below or the applicant may upload the assignment or enclose the assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period).

We, the above-named inventor(s) is/are the true & first inventor(s) for this Invention and declare that the applicant(s) herein is/are my/our assignee or legal representative.

(a) Date:

(b) Signature:

(c) Name: **Dr Soumya Ranjan Jena**

(ii) Declaration by the applicant(s) in the convention country

(In case the applicant in India is different than the applicant in the convention country: the applicant in the convention country may sign herein below or applicant in India may upload the assignment from the applicant in the convention country or enclose the said assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period)

I/We, the applicant(s) in the convention country declare that the applicant(s) herein is/are my/our assignee or legal representative. – **N.A.**

(ii) Date

(iii) Signature(s)

(iv) Name(s) of the signatory

(iii) Declaration by the applicant

We the applicant hereby declare that: -

[✓] We are in possession of the above-mentioned invention.

[✓] The complete specification relating to the invention is filed with this application.

[**x**] The invention as disclosed in the specification uses the biological material from India and the necessary permission from the competent authority shall be submitted by me/us before the grant of patent to me/us.

[✓] There is no lawful ground of objection(s) to the grant of the Patent to us.

[**x**] We are the true & first inventor(s).

[✓] We are the assignee or legal representative of true & first inventor(s).

[**x**] The application or each of the applications, particulars of which are given in Paragraph-8, was the first application in convention country in respect of my invention(s).

[**x**] We claim the priority from the above mentioned application(s) filed in convention country/countries and state that no application for protection in respect of the invention had been made in a convention country before that date by us or by any person from which I derive the title.

[**x**] Our application in India is based on international application under Patent Cooperation Treaty (PCT) as mentioned in Paragraph-9.

[**x**] The application is divided out of my /our application particulars of which is given in Paragraph-10 and pray that this application may be treated as deemed to have been filed on DD/MM/YYYY under section 16 of the Act.

[**x**] The said invention is an improvement in or modification of the invention particulars of which are given in Paragraph-11.

13. FOLLOWING ARE THE ATTACHMENTS WITH THE APPLICATION

(a) Form 2

Item	*Details*	*Fee*	*Remarks*
Complete/ provisional specification	No. of pages: 36	1600	Including Form 2, description,
No. of Claim(s)	No. of Claims = 40 No. of Pages = 8	-	Claim pages
Abstract	1		Abstract page
No. of Drawing(s)	No. of drawings = 3 and No. of pages =3		Drawing sheets

In case of a complete specification, if the applicant desires to adopt the drawings filed with his provisional specification as the drawings or part of the drawings for the complete specification under rule 13(4), the number of such pages filed with the provisional specification are required to be mentioned here.

b. Form 3: Statement and Undertaking
c. Form 5: Declaration as to inventorship
d. Power of Attorney
e. Form 28
f. Form 9

Total fee ₹ 16580/- is being paid online through electronic portal

We hereby declare that to the best of our knowledge, information and belief the fact and matters stated herein are correct and we request that a patent may be granted to us for the said invention.

Dated this 2nd day of November 2025.

Signature:

Name: Sudarshana Bandyopadhyay
(Regn No: IN/PA 2802)
Agent for the Applicant
Phn no.: 97488 18235
email: bandyopadhyay.sudarshana@gmail.com

To,
The Controller of Patents
The Patent Office,
at Kolkata

FORM 28

THE PATENTS ACT,

1970 (39 of 1970)

AND

THE PATENTS RULES, 2003

TO BE SUBMITTED BY A SMALL ENTITY /STARTUP/EDUCATIONAL INSTITUTION

[See rules 2 (fa), 2(fb), 2(ca) and 7]

1	Name, address and nationality.	We, SRJX RESEARCH AND INNOVATION LAB LLP, of the address Plot No - 3E/474, Sector-9, CDA, Post- Markat Nagar, Cuttack-753014, Odisha, India, applicant in respect of the patent application no. ________________ dated 2 November 2025 hereby declare that we are a micro entity in accordance with rule 2(fa) and submit the following document as a proof :
2	Documents to be submitted	
	i. For claiming the status of a **micro** entity:	
	A. For an Indian applicant: Evidence of registration under the Micro, Small and Medium Enterprises Act, 2006 (27 of 2006).	
3	To be signed by the applicant(s) / patentee (s) / authorised registered patent agent.	The information provided herein is correct to the best of my/our knowledge and belief. Dated this 2nd day of November 2025
4	Name of the natural person who has signed.	Signature: Sudarshana

Signature Not Verified

Digitally Signed.
Name: Sudarshana Bandyopadhyay
Date: 02-Nov-2025 17:16:43
Reason: Patent Efiling

	Designation and official seal, if any, of the person who has signed.	Sudarshana Bandyopadhyay Regn. No.: IN/PA 2802 Agent for the applicant Phn No. 9748818235 Email: bandyopadhyay.sudarshana@gmail.com To The Controller of Patents, The Patent Office, At Kolkata

FORM 9

THE PATENTS ACT, 1970

(39 of 1970)

&

THE PATENTS RULES, 2003

REQUEST FOR PUBLICATION

[See Section 11A(2); Rule 24A]

We, SRJX RESEARCH AND INNOVATION LAB LLP, of the address Plot No - 3E/474, Sector-9, CDA, Post- Markat Nagar, Cuttack-753014, Odisha, India, hereby request for an early publication of our Patent Application No. ____________________ filed on 2 November 2025 under Section 11A(2) of the Act.

Dated this 2nd day of November 2025

Sudarshana Bandyopadhyay
Regn No.: IN/PA 2802
Agent for the Applicants
Email: bandyopadhyay.sudarshana@gmail.com
Phn No: 9748818235

सत्यमेव जयते

INDIA NON JUDICIAL

Government of National Capital Territory of Delhi

₹100

e-Stamp

Certificate No.	:	IN-DL35961746213944X
Certificate Issued Date	:	16-Aug-2025 11:10 AM
Account Reference	:	IMPACC (IV)/ dl962703/ DELHI/ DL-ESD
Unique Doc. Reference	:	SUBIN-DLDL96270305293890128756X
Purchased by	:	SRJX RESEARCH AND INNOVATION LAB LLP
Description of Document	:	Article 48(c) Power of attorney - GPA
Property Description	:	Not Applicable
Consideration Price (Rs.)	:	0 (Zero)
First Party	:	SRJX RESEARCH AND INNOVATION LAB LLP
Second Party	:	ZAINAB SYED AND ASSOCIATES
Stamp Duty Paid By	:	SRJX RESEARCH AND INNOVATION LAB LLP
Stamp Duty Amount(Rs.)	:	100 (One Hundred only)

NOTARY
R.V. Singh
Advocate
Reg. No.2282
Commission
Expire On
24-10-2027
Area-Delhi
GOVT. OF INDIA

Please write or type below this line IN-DL35961746213944X

NOTARY
R.V. Singh
Advocate
Reg. No.2282
Commission
Expire On
24-10-2027
Area-Delhi
GOVT. OF INDIA

Statutory Alert:

1. The authenticity of this Stamp certificate should be verified at 'www.shcilestamp.com' or using e-Stamp Mobile App of Stock Holding. Any discrepancy in the details on this Certificate and as available on the website / Mobile App renders it invalid.
2. The onus of checking the legitimacy is on the users of the certificate.
3. In case of any discrepancy please inform the Competent Authority.

Signature Not Verified

Digitally Signed.
Name: Sudarshana Bandyopadhyay
Date: 02-Nov-2025 17:13:52
Reason: Patent Efiling

FORM-26
The Patents Act, 1970
(39 of 1970)
FORM FOR AUTHORIZATION OF A PATENT AGENT/OR ANY PERSON IN A MATTER OR PROCEEDING UNDER THE ACT
[See Sections 127 and 132; Rule 135]

I, **SRJX RESEARCH AND INNOVATION LAB LLP**, Indian, of the address SRJX RESEARCH AND INNOVATION LAB LLP, Plot No - 3E/474, Sector-9, CDA, Post- Markat Nagar, Cuttack-753014, Odisha, India, hereby authorize **Zainab Syed & Associates** having address 3E, Nawab Bhagwanpora, Lal Bazar, Srinagar, Jammu & Kashmir, 190023, India **(Mobile No.: +91 9748818235, Email: bandyopadhyay.sudarshana@gmail.com)** through **Ms. Sudarshana Bandyopadhyay (IN/PA 2802)** and **Ms. Meenu Sharma (IN/PA-2856)**, registered Indian Patent Agents, to act on our behalf and to further appoint attorney(s)/agent(s) in connection with the filing and prosecution of our patent applications for grant of Letters Patent, filing of request for examination, filing request for amendment, recordal of change of name and address, ownership, change of address of service in India, renewal of patent, recordal of assignments, filing and defending oppositions and infringement actions, restoration of patents, registration of documents and such other actions and all proceedings under the Patents Act, 1970 and the Patent Rules, 2003 and all such proceedings before the Patent Office or the Government of India or any Court in India and all acts and things as the said attorney may deem necessary or expedient in connection therewith or incidental thereto.

We further request that all notices, requisitions and communication relating thereto may be sent to such person/s at the corresponding address mentioned below:

Ground Floor, S-456, LGF, Greater Kailash – II, New Delhi – 110048, India,

(Contact No.: +91 9748818235; Email: bandyopadhyay.sudarshana@gmail.com)

We, hereby, revoke all previous authorizations, if any, in respect of the proceedings.

NOTARY
R.V. Singh
Advocate
Reg. No.2282
Commission
Expire On
24-10-2027
Area-Delhi
GOVT. OF INDIA

We, hereby, assent to the action already taken by the said person/s in the above matter.

Dated this 14th **day of August, 2025**

SRJX RESEARCH AND INNOVATION LAB LLP
Through:

Signature: Soumya Ranjan Jena

Name: Dr. Soumya Ranjan Jena

Company Seal: SRJX Research and Innovation Lab LLP
LLPIN: ACO-1435

To,
The Controller of Patents,
The Patent Office,
Kolkata

NOTARY
R.V. Singh
Advocate
Reg. No.2282
Commission
Expire On
24-10-2027
Area-Delhi
GOVT. OF INDIA

ATTESTED
Notary Public Delhi

16 AUG 2025

FORM 9

THE PATENTS ACT, 1970

(39 of 1970)

&

THE PATENTS RULES, 2003

REQUEST FOR PUBLICATION

[See Section 11A(2); Rule 24A]

We, SRJX RESEARCH AND INNOVATION LAB LLP, of the address Plot No - 3E/474, Sector-9, CDA, Post- Markat Nagar, Cuttack-753014, Odisha, India, hereby request for an early publication of our Patent Application No. ____________________ filed on 2 November 2025 under Section 11A(2) of the Act.

Dated this 2nd day of November 2025

Sudarshana Bandyopadhyay
Regn No.: IN/PA 2802
Agent for the Applicants
Email: bandyopadhyay.sudarshana@gmail.com
Phn No: 9748818235

FORM 3

THE PATENTS ACT,

1970 (39 of 1970)

and

THE PATENTS RULES,
2003

STATEMENT AND UNDERTAKING UNDER SECTION 8

(See section 8; Rule 12)

1. Name of the applicant(s).	We, SRJX RESEARCH AND INNOVATION LAB LLP, Plot No - 3E/474, Sector-9, CDA, Post-Markat Nagar, Cuttack-753014, Odisha, India hereby declare:
2. Name, address and nationality of the joint applicant.	(i) that we have not made any application for the same/substantially the same invention outside India Or (ii) that we who have made this application No dated 2nd November 2025 alone/~~jointly with~~ ...., made for the same/ substantially same invention, application(s) for patent in the other countries, the particulars of which are given below:

Name of the country	Date of application	Application No.	Status of the application	Date of publication	Date of grant
N.A.					

3. Name and address of the assignee	(iii) that the rights in the application(s) have been assigned to SRJX RESEARCH AND INNOVATION LAB LLP, Plot No - 3E/474, Sector-9, CDA, Post-Markat Nagar, Cuttack-753014, Odisha, India

Signature Not Verified

Digitally Signed.
Name: Sudarshana Bandyopadhyay
Date: 02-Nov-2025 17:13:52
Reason: Patent Efiling

	that we undertake that upto the date of grant of the patent by the Controller, we would keep him informed in writing the details regarding corresponding applications for patents filed outside India within six months from the date of filing of such application. Dated this 2nd day of November 2025
4. To be signed by the applicant or his authorized registered patent agent.	Sudarshana Signature. ....
5. Name of the natural person who has signed.	Sudarshana Bandyopadhyay Regn. No.: IN/PA 2802 Agent for the applicant Phn No. 9748818235 Email: bandyopadhyay.sudarshana@gmail.com
	To The Controller of Patents, The Patent Office, at Kolkata
Note.- Strike out whichever is not applicable;	