© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719698

Operations Control Centers for Freight, High-Speed, and Metro Rail in India: A Comparative Study of DFCCIL, NHSRCL, and Ahmedabad Metro

AARNAV AGARWAL[1], VISHNUPRASAD MANNADIAR[2]
[1]*BITS Pilani, Hyderabad*
[2]*Tata Consulting Engineers Limited*

Abstract- In this study, three OCC types are compared across different railway systems, focusing on their system design, control methods, subsystem integration, and operational performance. It uses official project documents related to the railway standards (EN 50126/28/29, IEC 61508, IEC 62290) and OEM material. The DFCCIL Operation Control centres serve as logistics-centric command nodes, integrating inputs from Train Management Systems (TMS), the Dedicated Freight Information System (DFIS), and a real-time monitoring architecture. These integrated subsystems are programmed to accommodate heavy freight traffic loads of 25-32.5 Tonnes with an operational speed of 100 km/h. In contrast, the proposed OCC of NHSRCL in Sabarmati should be driven by Shinkansen technology (as in Japan), with European Train Control System (ETCS) Level 2 signalling and SIL 4 safety protocols to ensure safety at high speeds of 320km/h. Ahmedabad Metro's OCC is a CATC/CBTC-based control room focused on passenger trains, with a 90-second headway. The paper compares current OCCs based on various parameters, as tabulated, such as throughput, latency, availability, and safety integrity levels. This comparison is based on published corridor capacities and ETCS/CBTC design references. The paper concludes with lessons for OCC design, cyber-physical integration, and RAMS engineering across freight, high-speed, and metro areas.

Index Terms- Operations Control Center (OCC), DFCCIL, NHSRCL, GMRCL, Train Communication

I. INTRODUCTION

In railway transportation, the OCC acts as the central point for railway transportation activities with the aid of technology, expertise, and processes that make train operation safe, effective, and reliable. Modernday OCCs incorporate signaling, traction power control, telecommunication services, security surveillance, and data analysis under a single command system. OCCs are extremely important for the decision-making process related to the regulation of trains and incidents.

Indian railway systems have undergone a phase of modernization, during which three rail systems have developed: the metro system, dedicated freight corridors, and high-speed railways. Each system is represented by an OCC for that system, such as GMRC, DFCCIL, and NHSRCL. The development of each rail system depicts the transformation of Indian rail operations. Each OCC is designed for a specific purpose and is defined by unique requirements, ranging from 90 seconds in the metro system to 320km/h on high-speed railways.

The GMRC runs metro services in urban regions of Gujarat. It marks the beginning of a high-frequency, customer-oriented urban transit system. The DFCCIL manages the Western and Eastern Dedicated Freight Corridors totaling 2,741 route kilometers, designed to provide high-axle-load freight service. The OCCs are involved in optimizing throughput using the Train Management System (TMS), ensuring complete SCADA coverage (including the revolutionary NonTraction Power Supply SCADA), and managing asset health. The Mumbai-Ahmedabad project, which is India's first high-speed rail project with a design speed of 320 km/h, is being developed by NHSRCL. The OCC (under development at Sabarmati) represents the peak of rail operational efficiency, combining high-speed train control and Japanese Shinkansen technology with the ETCS Level 2 signaling system.

II. RESEARCH METHODOLOGY

The study is based on a structured literature review of official project documents, government and multilateral reports, standards, and peer-reviewed technical publications relevant to the OCCs of DFCCIL, NHSRCL's MAHSR project, and GMRC's Ahmedabad Metro along with the site visit across the existing facilities of GMRC & DFCCIL. Primary system characteristics such as corridor length, design speed, train capacity, and indicative service plans were extracted from NHSRCL operational plan material, Gujarat state/GMRC detailed project reports (DPRs), and central government communications on the Dedicated Freight Corridor (DFC) program. OCC-specific information (location, architectural features, and high-level functions) was taken from DFCCIL and GMRC corporate disclosures, media releases quoting these entities, and multilateral or policy notes summarizing MAHSR operational arrangements. [3] [10] [17]

For control philosophy and subsystem integration, the study synthesizes domain standards (EN 50126/28/29, IEC 61508, IEC 62290), ETCS and CBTC reference descriptions, Indian Railways technical handbooks on CTC/CBTC, and peer-reviewed research on SCADA- and PLC-based railway control. Safety integrity allocations and automation grades are inferred from standards-based analyses of CBTC and ETCS, notably work showing ATP subsystems at SIL 4 and ATO/ATS at SIL 2 in CBTC architectures, and CENELEC guidance for vital signaling. [23] [35]

Non-authoritative blogs and opinion pieces were excluded unless they directly reproduced or linked back to primary documents, in which case only the underlying primary material was used.

Things like project specific OCC design drawings, detailed RAMS allocations, and real-time performance logs are not publicly disclosed for either of the three systems, hence limiting our analysis to high level system architecture and performance targets derived from official summaries and standards rather than detailed as-built configurations. Project-specific latency or availability analysis aren't publicly available for DFCCIL and NHSRCL, also for Ahmedabad metro OCC signaling chains were found; indicative values presented in the performance table are therefore explicitly labelled as derived from generic ETCS/CBTC and RAMS literature rather than measured system KPIs. Similarly, SIL certificates for each of the three subsystems aren't available publicly hence they are taken from the standards for comparable ETCS and CBTC architectures and should be interpreted as justified engineering expectations rather than verified certifications. [27]

III. SYSTEM OVERVIEW

A. DFCCIL FREIGHT OCCs

The Western and Eastern Dedicated Freight Corridors (WDFC and EDFC) combined constitute nearly 2,741 route km of high capacity freight only lines designed for 25 tonnes axle loads (upgradable to 32.5 t on some structures), 1,500 m train lengths, and maximum freight speeds of around 100 km/h. Government disclosures indicate that the DFC program aims to raise average freight speeds from roughly 25–26 km/h on mixed traffic lines to about 70 km/h on the corridors, while enabling heavy haul, double stack container operations. As of 2025–26, DFCCIL reports operating around 300 freight trains per day across its network, implying per corridor throughputs of the order of 150 trains/day, managed centrally by the OCCs as commissioning progresses. [1] [8]

Figure 1: DFCCIL OCC(WDFC)

DFCCIL operates at two large OCCs: one for the EDFC at Prayagraj and another for the WDFC at Sabarmati, Ahmedabad. The Sabarmati OCC is a 3.07 acre facility with a built up area of roughly 12,867 m² and a 72 m curved real time monitoring video wall, supported by two war rooms and a disaster management room, which together provide complete corridor wide visibility of train positions, track layouts, and power systems. The Prayagraj OCC for the EDFC constitutes a control theatre of about 1,560 m² with an over-90 m video wall and integrates the Train Management System (TMS) and SCADA to supervise both train operations and 2×25 kV traction power equipment across the full corridor. [1] [2]

The OCCs are assisted by DFCCIL's Dedicated Freight Information System (DFIS), which provides real time train running, section status, and operational information to support path planning, detention analysis, and coordination with Indian Railways

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719698

control offices. Safety related condition monitoring subsystems, such as Machine Vision Inspection Systems (MVIS) and Hot Axle Box Detectors (HABD), feed alarms and diagnostics to the OCC to enable early detection of rolling stock defects and timely interventions are essential for fault detection and maintenance. These capabilities position DFCCIL OCCs as logistics driven command centres, focusing on throughput maximization, predictive maintenance, and real time coordination with the legacy mixed traffic network. [5]

B. NHSRCL MAHSR HIGH-SPEED OCC

The Mumbai–Ahmedabad High Speed Rail (MAHSR) corridor is a 508 km standard-gauge high-speed line being implemented by NHSRCL with Japanese cooperation, designed for 350 km/h and an initial operating speed of 320 km/h. Official operational plans envisage 12 stations and an initial service plan of 35 trains per day per direction, rising to 105 trains per day by the 30th year of operation, with peak-hour headways of 20 minutes initially and up to about 7–8 minutes in later years, corresponding to tens of thousands of seats per day per direction. The corridor is largely on a viaduct, with significant tunneling, including a 21 km tunnel with an undersea segment, underscoring the need for tightly integrated operations and safety monitoring by the OCC. [10]

NHSRCL and associated policy and multilateral documents consistently state that the MAHSR Operational Control Center will be in Sabarmati, Ahmedabad, co-located with a major depot and workshop complex. The technical basis of the system is Shinkansen technology transferred from Japan, covering rolling stock, signaling, and design standards, including Japanese slab-track and Automatic Train Control (ATC) concepts. A major signaling and telecom contract awarded to a consortium including Siemens specifies deployment of European Train Control System (ETCS) Level 2-based signaling and train control, with centralized traffic management designed for speeds up to 350 km/h and continuous wireless communication between trains and Radio Block Centers (RBCs). [10] [14]

In line with Shinkansen and ETCS practice, high-speed operations are expected to rely on continuous ATP enforced from the OCC through RBCs and interlockings, with no routine reliance on lineside signals and stringent braking-curve supervision. The OCC must therefore integrate high-availability CTC with ETCS L2 and Japanese ATC-derived protective functions, interface with earthquake detection systems, and orchestrate depot and maintenance operations to maintain the extremely high punctuality expected of a high-speed passenger service. [32]

C. AHMEDABAD METRO OCC

Ahmedabad Metro, implemented by GMRC, is a standard-gauge urban metro system serving Ahmedabad, Gandhinagar, and the GIFT City region, with a network length on the order of 60–70 km across two main corridors in Phase 1 and additional extensions in Phase 2. The system employs a Continuous Automatic Train Control (CATC) system based on CBTC, including Automatic Train Protection (ATP), Automatic Train Operation (ATO), and Automatic Train Supervision (ATS), designed for driverless-capable operations (GoA 3) with nominal train headways as low as 90 s and design speeds around 80 km/h with typical commercial speeds in the low 30 km/h range. [17] [24]

Figure 2 Ahmedabad Metro OCC

GMRC's technology overview and annual reporting indicate that the Apparel Park depot houses a fully functional Operations Control Center, a depot control center, signaling and telecom equipment rooms, a UPS, and associated support spaces. The metro uses integrated telecom systems, including fiber-optic networks, train radio, public address, passenger information, and centralized clock systems, as well as SCADA for power and auxiliary systems and an automatic fare collection system. CBTC-based CATC

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719698

is designed to support 90 s headways, driverless-operation readiness, and regenerative-braking-equipped rolling stock, positioning the OCC as the central node for high-frequency, passenger-oriented operations in an urban environment. [17]

The Ahmedabad Metro OCC conceptually resembles other Indian CBTC metros, such as Hyderabad, where the OCC supervises train movements, signaling, traction power, and station systems using CBTC, SCADA, and integrated communications, acting as both primary and backup control center in emergencies. For Ahmedabad, the contract and DPR materials for later phases explicitly call for integrating Phase II SCADA with the existing OCC/backup control center (BCC) via fiber-optic networks and RTU/SCADA interfaces, confirming a centralized yet extensible control architecture.

Table 1 Design and Operational Specifications of the three rail corridors

Parameter	DFCCIL Freight Corridors	Mumbai–Ahmedabad HSR (NHSRCL)	Ahmedabad Metro (GMRC)
Primary function	Heavy-haul, long-distance freight transport (double-stack containers, bulk commodities).	High-speed intercity passenger service using Shinkansen-derived technology.	High-frequency urban mass transit in Ahmedabad–Gandhinagar region.
Approximate route length	WDFC ≈ 1,504 km, EDFC ≈ 1,337 km (≈ 2,741 km total).	≈ 508 km between Mumbai and Ahmedabad.	Phase I ≈ 38 km; network including Phase II extensions ≈ 60–70 km.
Track gauge	Indian broad gauge (1,676 mm).	Standard gauge (1,435 mm).	Standard gauge (1,435 mm).
Design speed	Max freight speed ≈ 100 km/h.	Design speed 350 km/h, operating speed 320 km/h.	Max design speed ≈ 80 km/h, commercial ≈ 30–35 km/h.
Axle load/train configuration	25 t axle load (upgradable to 32.5 t on some structures); train length up to ≈ 1.5 km.	High-speed EMUs (10- and 16-car sets), passenger-only.	3-car metro trainsets initially, with provision for longer formations depending on the corridor.
Headway/capacity basis	Capacity basis ≈ 132 trains/day/direction on EDFC, with planned network capacity ≈ 250 trains/day; current traffic ≈ 300+ trains/day combined.	Initial 35 trains/day/direction, increasing up to 105 trains/day/direction (≈ 92,900 seats/day/direction) in later years.	Minimum design headway 90 s; PHPDT up to ≈ 18,864 passengers in peak corridor scenarios.
Typical signaling/control	CTC/TMS with modern electronic interlockings; freight-oriented route and path management.	ETCS Level 2-based signalling with Shinkansen-derived ATC and continuous ATP.	CBTC-based Continuous Automatic Train Control (CATC: ATP, ATO, ATS) ready for GoA 3.
Power supply	2×25 kV AC high-capacity traction system with SCADA-controlled substations.	25 kV AC OHE with dedicated traction substations and high-speed-grade electrification.	25 kV AC traction with SCADA-controlled RSS/TSS and auxiliary systems.

IV. OCC ARCHITECTURE COMPARISON

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719698

A. CENTRALIZED VERSUS DISTRIBUTED DESIGN:

Table 2 Design Comparison

Dimension	DFCCIL OCCs	NHSRCL MAHSR OCC	Ahmedabad Metro OCC
Supervision model	Strongly centralized OCCs with large theatre-style control rooms and corridor-wide visibility.	Centralized supervisory OCC with distributed ETCS L2 RBCs and interlockings for vital control.	Centralized ATS/SCADA supervision with distributed CBTC zone controllers and CBIs for vital control.
Safety-critical logic location	Primarily in field interlockings and ATP subsystems; OCC applications are non-vital.	Vital logic in ETCS RBCs, interlockings, and onboard ATC; OCC non-vital but safety-related.	Vital ATP/CBI logic split between onboard and wayside; OCC ATS non-vital supervisory.
Scope of control	Multi-state freight corridors (>1,000 km) with integration to Indian Railways network.	Single HSR corridor with multiple depots and complex structures (viaducts, tunnels, sea tunnel).	Urban metro network with multiple corridors and closely spaced stations.

B. REDUNDANCY AND FAILOVER

Public descriptions of DFCCIL OCCs highlight war rooms and disaster management rooms, but do not detail redundancy schemes; based on standard CTC design and EN 50126 RAMS principles, such OCCs are typically engineered with redundant servers, dual power feeds (often backed by UPS and DG sets), and duplicated communication paths to maintain control under single-point failures. DFCCIL's emphasis on AI-ready systems and green-building features such as rooftop solar and rainwater harvesting at Sabarmati suggests additional infrastructural resilience, though explicit failover architectures (e.g. hot-standby OCC or secondary control sites) are not disclosed. [2]

High-speed ETCS L2 systems are normally engineered to SIL 4 for vital functions and to meet stringent availability targets, which in practice drives extensive redundancy in RBCs, interlockings, servers, and telecom bearers, often including dual diverse routes and hot-standby configurations. Siemens' ETCS solutions and ETCS interoperability safety requirements under European standards emphasize redundant RBCs and communication links to avoid loss of supervision, and it is reasonable to infer that MAHSR's OCC–RBC complex will adopt similar redundancy patterns even though specific topologies are not publicly documented.

For Ahmedabad Metro, CBTC reference architectures and RDSO's CBTC handbook describe redundant zone controllers, dual communication links (often using WLAN with overlapping access points), and duplicated ATS/SCADA servers to achieve high availability and fail-safe behavior. Industry analyses of CBTC reliability cite target availabilities around 99.9–99.98 % for signaling and communication, achieved through hardware redundancy, diversified communication paths, and robust recovery procedures, and metros such as Dubai have reported 99.9 %-class CBTC availability, indicating the level of redundancy typically expected in systems akin to Ahmedabad.

Table 3 Redundancy Matrix

Aspect	DFCCIL OCCs	NHSRCL MAHSR OCC	Ahmedabad Metro OCC
OCC control room redundancy	War rooms and disaster management rooms indicate organizational redundancy; technical details not fully published but central CTC practice implies redundant servers and power.	Expected to follow high-speed practice with hot-standby servers, dual OCC server rooms, and possibly backup control facilities, though project-specific designs are not public.	Typically, primary OCC and BCC with redundant ATS/SCADA servers and dual communication networks, as indicated in Phase II SCADA integration requirements and CBTC design practice.

Server and application redundancy	CTC/TMS, DFIS, and SCADA servers likely deployed in redundant clusters per EN 50126 RAMS guidance; explicit DFCCIL schematics not published.	ETCS L2 and high-speed CTC implementations use dual or triple-modular redundant servers for RBCs and TMS; MAHSR expected to adopt similar architecture via OEM implementations.	CBTC ATS and SCADA deployed on redundant server pairs with automatic failover, consistent with CBTC solutions and GMRC technical specifications.
Communication path redundancy	Dual fibre rings and diverse routing typical for corridor telecom and SCADA networks.	Redundant fibre backbones for RBCs and interlockings plus overlapping GSM-R/FRMCS coverage for ETCS.	Dual fibre rings and overlapping radio coverage (WLAN) for CBTC and telecom; specified in CBTC and SCADA design guides.

C. DATA-CENTRE AND HMI ARCHITECTURE:

DFCCIL OCCs feature theatre-style control rooms with large curved video walls displaying corridor synoptics, train positions, and power system schematics, fed by TMS, DFIS, SCADA, and condition-monitoring subsystems. Standard CTC product descriptions indicate that OCC data centers for such systems comprise clustered application servers (TMS/CTC, DFIS, SCADA), database servers, interface gateways (to CRIS, FOIS, crew management, etc.), and networks providing terminals and workstation HMIs for controllers, typically organized by section or functional role.

In MAHSR, the OCC data center must host ETCS L2 RBCs or their interfaces, Centralized Traffic Control, SCADA for traction and station systems, and interfaces to maintenance and depot management systems, all engineered to EN 50126/29 RAMS principles and integrated with Shinkansen-style General Control Center HMI for an integrated view of train operations and infrastructure status. The HMI is expected to include track-occupancy and movement-authority views, speed profiles, timetable adherence dashboards, and alarm panels for infrastructure and environmental events (e.g., earthquakes), analogous to Shinkansen and ETCS control centers described in Japanese and European literature.

Ahmedabad Metro's OCC data-centre architecture, as inferred from ATS and SCADA subsystem overviews, consists of central and local ATS server racks, mimic panels, ATS workstations, and SCADA servers interfacing with station RTUs, traction power equipment, and building systems, with man–machine interfaces providing line overviews, timetables, maintenance monitoring, and control panels. GMRC's technology documents confirm that CBTC-based CATC uses radio communication between trackside and train, while SCADA uses integrated fibre-optic networks, with the OCC HMI showing train positions, signalling states, and power system status similar to other modern metros such as Hyderabad. [17]

V. FUNCTIONAL COMPARISON

A. TRAIN CONTROL & DISPATCHING LOGIC:

Table 4 Train Control and Dispatching Logic Comparison

Function	DFCCIL OCCs	NHSRCL MAHSR OCC	Ahmedabad Metro OCC
Train localisation basis	Track circuits/axle counters via interlockings reported to TMS/CTC.	Continuous train position reporting via ETCS L2 (e.g. GSM-R) and balise/location data.	Continuous localisation via CBTC (radio-based, moving block) with high granularity.
Movement authority generation	Route setting and block occupation managed by interlockings; CTC automates	RBCs compute movement authorities using ETCS logic, interlocking states, and braking curves.	CBTC zone controllers generate movement authorities; ATO executes speed/dwell commands.

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719698

	route requests and path allocation.		
Dispatching objective	Maximise tonne-km and train throughput; coordinate with Indian Railways; manage heavy-haul constraints.	Maintain precise timetables and safe separation at very high speed; optimise seat-km and punctuality.	Maintain short, stable headways and service regularity; minimise passenger waiting and crowding.
Automation grade	Largely manual driving with centralised route setting; no CBTC/ATO.	High-speed ATP; driving may be manual with ATC supervision rather than fully automatic.	CBTC-based GoA 2–3: automatic train operation under driver or attendant supervision; architecture capable of GoA 3.

B. SCADA AND TRACTION POWER CONTROL

Function	DFCCIL OCCs	NHSRCL MAHSR OCC	Ahmedabad Metro OCC
Traction power SCADA	Integrated with OCC to monitor and control 2×25 kV substations, sectioning, and paralleling posts.	High-speed SCADA for 25 kV substations and tunnel/viaduct power systems; integrated with OCC for rapid isolation and protection coordination.	SCADA for 25 kV RSS/TSS and station auxiliaries, providing central control for breakers, feeders, and energy optimization.
Station / building SCADA	Limited – focus on freight terminals and yards; fewer passenger facilities.	Major passenger stations with building services expected to be tied into SCADA and OCC (HVAC, PSDs, emergency systems).	Extensive station-level SCADA (lifts, escalators, ventilation, lighting, fire systems) under OCC supervision.
Energy management	Focus on efficient operation of high-capacity traction supply and heavy-haul trains (reduced detentions, optimised operation).	High-speed operations require careful management of traction loads and regeneration, handled through SCADA and traction control.	Metro SCADA used to manage maximum demand and power factor, as noted in GMRC reports.

C. INTEGRATION AND INTERFACE ENGINEERING

Table 5 Interface Comparison

Interface domain	DFCCIL OCCs	NHSRCL MAHSR OCC	Ahmedabad Metro OCC
Signalling	CTC/TMS interfaces to station interlockings, track circuits, and signals.	OCC interfaces to ETCS L2 RBCs and interlockings and Shinkansen ATC elements	OCC ATS interfaces to CBTC zone controllers and CBIs.
Telecom	Fiber-optic backbone, GSM-R/other radio systems; links to Indian Railways systems (COA, FOIS).	Fiber backbone, GSM-R/FRMCS for ETCS; integration of voice and data for HSR operations.	Fiber backbone, radio communication (WLAN) for CBTC; integration with PA/PIDS and CCTV.
Rolling stock/depots	DFIS and condition-monitoring (MVIS/HABD) interfaces; crew/rake management systems.	Depot and maintenance systems at Sabarmati, Surat, Thane; high-speed EMU maintenance interfaces.	Depot control center, RS diagnostics, TCMS; tight coupling with ATS for stabling and deployment.

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719698

Station / passenger systems	Freight-terminal systems, interchange coordination with IR; limited passenger interfaces.	Passenger information, PSDs, crowd management, emergency systems (expected by analogy with HSR practice).	AFC, PA/PIDS, crowd control, safety systems fully integrated with OCC..

VI. PERFORMANCE METRICS

A. CORRIDOR-LEVEL THROUGHPUT AND CAPACITY

For DFCCIL, public sources state that the EDFC is designed to handle around 132 trains daily in each direction, with current operations already reaching approximately 140 trains/day on several sections and an overall capacity of about 250 trains/day on the full corridor. Network-wide, DFCCIL reports approximately 300 or more trains per day on both corridors combined, which OCCs at Prayagraj and Sabarmati must supervise with adequate margins for growth. [7]

MAHSR's operational plan specifies an initial 35 trains per day per direction, increasing to 51, 64, and 105 trains per day in later years as demand grows and train configurations transition from 10-car to 16-car sets, yielding up to about 92,900 seats per direction per day by the 30th year. This translates into peak-hour train frequencies of 3–8 trains per hour depending on year and configuration, which the OCC must schedule and regulate while maintaining high-speed safety margins.

Ahmedabad Metro's DPR and related documentation specify CATC/CBTC designed for 90 s minimum headway and peak-hour peak-direction capacities on the order of 18,864 passengers per hour per direction on some corridors, depending on train length and headway. With 90 s headways, the OCC must routinely manage up to 40 train movements per hour per direction on a line, far exceeding the train frequency on DFCCIL and MAHSR corridors but at far lower speeds.

B. LATENCY, AVAILABILITY, AND SIL TABLE

The following table consolidates publicly reported throughput figures and indicative latency, availability, and safety integrity level values. Where project-specific data were not found, entries are explicitly labelled as derived from generic CBTC/ETCS or RAMS literature rather than from as-built project data.

Table 6 LATENCY, AVAILABILITY, AND SIL TABLE COMPARISION

System/ OCC	Throughput (representative)	Signalling / control latency (indicative)	Target availability (indicative)	Safety Integrity Levels (key subsystems)
DFCCIL freight OCCs (Prayagraj, Sabarmati)	Design capacity ≈132 trains/day per direction on EDFC; current operations ≈140 trains/day on EDFC sections and ≈300 trains/day network-wide across DFCs.	No project-specific latency figures published; heavy-haul CTC/SCADA typically operate with control-loop and indication latencies on the order of 1–2 s for route commands and several hundred ms for field indication, derived from CTC/SCADA practice.	No explicit DFCCIL OCC availability target published; RAMS guidance for vital signalling and CTC systems commonly leads to design targets ≥99.9 % availability for control systems to meet network	Vital signalling/interlocking and ATP functions in modern mainline systems are generally engineered to SIL 4 under EN 50129, while traffic management, DFIS, and SCADA supervisory layers are typically non-vital at SIL 1–2; DFCCIL is expected to follow this partitioning though project-specific

			punctuality and safety goals.	SIL certificates are not public.
NHSRCL MAHSR OCC (Sabarmati)	Initial plan: 35 trains/day per direction, increasing to 105 trains/day per direction with 10- and 16-car sets, corresponding to up to ≈92,900 seats/day per direction in mature stage.	ETCS L2 and Shinkansen-style ATC architectures rely on near-continuous train–RBC communication; while no MAHSR-specific latency figures are published, ETCS and ATC literature indicate continuous supervision with message cycles in the sub-second to few-seconds range sufficient to maintain safe braking-curve enforcement at 320 km/h.	High-speed rail signalling and control are typically designed for very high availability (≳99.99 %) to meet punctuality targets, as implied by RAMS standards and high-speed practice, though explicit MAHSR OCC availability numbers are not yet public and this value should be treated as an indicative industry target.	ETCS L2 train protection and interlocking functions are normally certified to SIL 4 under EN 50129, while traffic management and non-vital OCC applications operate at lower SILs; Siemens' ETCS solutions and European regulatory practice confirm SIL 4 requirements for vital subsystems, which are expected to apply to MAHSR even though specific certificates are not published.
Ahmedabad Metro OCC (GMRC)	CBTC system dimensioned for 90 s headway and PHPDT ≈18,864 on some corridors with 3-car trains, implying up to 40 trains/hour/direction during peaks.	CBTC design references show movement authorities updated every ≈0.5 s with communication and processing delays ≤2 s between movement of an obstruction and extension of a following train's authority, and end-to-end radio latencies targeted below ≈10 ms, providing a basis for the 90 s headway claim; these values are indicative of CBTC performance, not Ahmedabad-specific measurements	CBTC availability analyses and case studies (e.g. Dubai Metro) demonstrate signalling and communications availability on the order of 99.9–99.98 %, often targeting "five-nines" at the communication layer, representing typical design goals for metros similar to Ahmedabad;	Peer-reviewed CBTC safety studies show ATP subsystems and CBIs classified at SIL 4, with ATO and ATS at SIL 2, a partitioning aligned with EN 50126/28/29 and IEC 61508 that is applicable to CBTC metros such as Ahmedabad.

All latency and availability values labelled as indicative are “Derived based on standard industry practice” rather than project-specific measurements; they should be interpreted as design-target orders of magnitude referenced from CBTC/ETCS and RAMS literature rather than empirical KPIs for the three OCCs.

VII. CORE COMPARATIVE INSIGHTS

A. DFCCIL: HEAVY-HAUL, PREDICTIVE, LOGISTICS-DRIVEN OCC

DFCCIL’s OCCs are optimised for managing heavy, long freight trains over long distances with high axle loads and moderate speeds, with performance measured in terms of tonne-kilometres, train-throughput, and integration with ports and industrial clusters rather than passenger minutes. The integration of DFIS, CTC/TMS, SCADA, and condition-monitoring subsystems such as MVIS and HABD into the OCC supports predictive maintenance and data-driven logistics decisions, enabling informed management of paths, detentions, and exceptions. The OCC thus acts as a logistics command centre that trades off speed, axle load, and energy efficiency within safety constraints defined by mainline signalling standards.

B. NHSRCL: ULTRA-HIGH SAFETY, PRECISION TIMING, FAIL-SAFE ARCHITECTURE

NHSRCL’s MAHSR OCC is centred on ultra-high-speed passenger operations where safety (SIL 4 train protection) and precision timing dominate design, with ETCS L2 and Shinkansen ATC providing continuous ATP and automatic enforcement of braking curves at up to 320 km/h. Corridor capacity is increased through reduced headways and high design speeds, but operational philosophy remains conservative, prioritising safe separation and robust response to hazards such as earthquakes, for which high-speed rail systems deploy specialised detection and emergency-braking integration. The OCC is thus a safety-critical supervisory hub coordinating RBCs, ATC, SCADA, and depot systems to maintain extremely high safety and punctuality levels.

C. AHMEDABAD METRO: HIGH-FREQUENCY, PASSENGER-CENTRIC OCC

Ahmedabad Metro’s OCC is designed primarily for high-frequency urban passenger service, where CBTC-based CATC provides continuous train localisation and automatic train control to achieve headways down to 90 s and high PHPDT figures. Safety is provided by SIL 4 ATP and interlocking within the CBTC framework, but OCC operations are dominated by service regulation, passenger information, and station-system coordination aimed at minimising passenger waiting times and managing crowding. The OCC thus acts as a passenger-centric operations hub that balances frequency, reliability, and passenger-experience metrics more than axle-load or energy-throughput metrics.

D. INTEROPERABILITY AND MULTI-VENDOR INTEGRATION

DFCCIL OCCs must interface with Indian Railways’ signalling and control systems, FOIS, crew management, and station control, often supplied by different vendors and legacy systems, making interface control documents (ICDs) and rigorous integration testing essential. Multi-vendor integration is particularly critical for DFIS, which aggregates data from OCC, Indian Railways control offices, and terminals.

MAHSR involves integration of Japanese Shinkansen-derived technology with ETCS L2-based signalling and Indian infrastructure and regulatory frameworks, creating complex multi-vendor and multi-standard interfaces at signalling, rolling stock, power, and civil interfaces. Ensuring consistent safety cases in accordance with EN 50126/29 and IEC 61508 across these interfaces is a significant engineering challenge.

Ahmedabad Metro’s OCC integrates CBTC signalling, SCADA, telecom, AFC, and station systems from different suppliers (e.g. Nippon Signal for ATS/CBI and other OEMs for SCADA and telecom), necessitating robust systems engineering and interface management. Standards such as IEC 62290 and EN 50126/28/29 provide a framework, but actual integration requires careful coordination and validation, particularly where CBTC and SCADA share common networks.

VIII. CONCLUSION

DFCCIL, NHSRCL, and GMRC’s Ahmedabad Metro exemplify three distinct yet converging paradigms of railway operations control in India: freight-optimized heavy-haul corridors, ultra-high-speed passenger operations, and high-frequency urban metros. Despite differences in speed, load, and service patterns, their OCCs share core architectural themes of centralized supervision, distributed safety-critical control, SCADA integration, and standards-based RAMS engineering, underpinned by modern telecom backbones.

REFERENCES

[1] Dedicated Freight Corridor Corporation of India Ltd., Public Information Brochure, DFCCIL, New Delhi, India, Feb. 2012. https://dfccil.com/upload/Public_Information_Brochure_-_Feb2012.pdf

[2] Dedicated Freight Corridor Corporation of India Ltd., Corporate Plan (Revised 01.12.2020), DFCCIL, New Delhi, India, 2020. https://dfccil.com/images/uploads/img/Revised_01122020_corporate-plan_9LSK_JMUV_5577.pdf

[3] Ministry of Railways, Dedicated Freight Corridor (DFC) Project – Project Brochure, Railway Board, New Delhi, India. https://indianrailways.gov.in/railwayboard/uploads/directorate/infra/downloads/dfc_project.pdf

[4] Dedicated Freight Corridor Corporation of India, Objective of the Western Dedicated Freight Corridor, Ministry of Railways, New Delhi, India. https://forestsclearance.nic.in/writereaddata/Addinfo/0_0_31121124312231ObjectiveoftheWesternDedicatedFreightCorridor.pdf

[5] UNESCAP, Dedicated Freight Information System (DFIS) – Concept and Architecture, UNESCAP Rail Transport Division, Bangkok, Thailand. https://www.unescap.org/sites/default/d8files/event-documents/DFIS.pdf

[6] JICA, Attachment I.1.2 – DFC Western Corridor, Preparatory Survey for Dedicated Freight Corridor (Phase 2) (II), JICA, Tokyo, Japan, Mar. 2012. https://openjicareport.jica.go.jp/pdf/12067773_03.pdf

[7] A. P. Agarwal et al., Dedicated Freight Corridor: Current Challenges, Transportation Research Procedia (WCTR), IIM Bangalore, 2016. https://www.iimb.ac.in/sites/default/files/inline-files/Transportation%20Research%20Procedia_WCTR.pdf

[8] Dedicated Freight Corridor Corporation of India Ltd., Annual Report (English), DFCCIL, New Delhi, India https://dfccil.com/upload/AR-FINAL_English.pdf

[9] Dedicated Freight Corridor Corporation of India Ltd., DFC Journal – September 2019 Issue, DFCCIL, New Delhi, India. https://dfccil.com/upload/DFC_Journal_issue_sep_19.pdf

[10] National High Speed Rail Corporation Ltd., MAHSR Project Operational Plans, NHSRCL, New Delhi, India. https://www.nhsrcl.in/en/project/mahsr-project-operational-planss

[11] National High Speed Rail Corporation Ltd., Joint Feasibility Study for Mumbai–Ahmedabad High Speed Rail – Volume 3 (Technical Details), NHSRCL, New Delhi, India. https://www.nhsrcl.in/sites/default/files/technical-details/2019-07/EI_CR15137_Vol-3.pdf

[12] National High Speed Rail Corporation Ltd., Project Overview of High-Speed Rail Corridor – MAHSR, NHSRCL, New Delhi, India. http://www.nhsrcl.in/en/project/project-overview

[13] National High Speed Rail Corporation Ltd., Feasibility Study Report for MAHSR – Volume I, NHSRCL, New Delhi, India, 2019. https://www.nhsrcl.in/en/project/feasibility-study-report

[14] P. Mishra, Mumbai Ahmedabad High Speed Rail Project (MAHSR), IHRA-HSR, 2021. https://www.ihra-hsr.org/cms_assets/en_activities_20210625_PrashantMishra.pdf

[15] JICA, Project for the Construction of Mumbai–Ahmedabad High Speed Rail, JICA, Tokyo, Japan, 2025. Available: https://www.jica.go.jp/english/our_work/social_environmental/id/asia/south/india/c8h0vm00009v1ylc.html

[16] National High Speed Rail Corporation Ltd., 6th Annual Report, NHSRCL, New Delhi, India, 2022–23. https://www.scribd.com/document/637103519/

NHSRCL-6th-Annual-Report-eng-30-01-2023-1

[17] Gujarat Metro Rail Corporation Ltd., Ahmedabad Metro Rail Project – Phase I Detailed Project Report, GMRC, Gandhinagar, India, Feb. 2014. https://www.gujaratmetrorail.com/wp-content/uploads/DPR/Ahmedabad-Phase-I_-DPR_OLD_2014PDF_opt.pdf

[18] Gujarat Infrastructure Development Board, DPR for Ahmedabad Metro – Executive Summary, GIDB, Gandhinagar, India. https://www.gidb.org/pdf/3_Executive_Summary.pdf

[19] Gujarat Metro Rail Corporation Ltd., Ahmedabad Metro Rail Project – Phase II DPR (Mar 2019), GMRC, Gandhinagar, India. https://www.gujaratmetrorail.com/wp-content/uploads/DPR/Phase-II-DPR_Mar-19_opt.pdf

[20] Gujarat Metro Rail Corporation Ltd., Reports & Downloads – ESIA/DPR Documents, GMRC, Gandhinagar, India. https://www.gujaratmetrorail.com/reports/

[21] Gujarat Metro Rail Corporation Ltd., 15th Annual Report 2024–25, GMRC, Gandhinagar, India. https://www.gujaratmetrorail.com/wp-content/uploads/2026/05/Annual-Report-for-FY-2024-2025.pdf

[22] Ahmedabad Metro Rail Project DPR, Revised Ahmedabad Metro DPR – Salient Features and Train Operation Plan, 2015. https://www.scribd.com/document/344827713/Revised-Ahmedabad-Metro-DPR-Compiled-20th-May-2015-pdf

[23] RDSO / CAMTECH, An Introductory Handbook on Centralized Traffic Control (CTC), RDSO, Lucknow, India. https://rdso.indianrailways.gov.in/uploads/An%20Introductory%20handbook%20on%20Centralized%20Traffic%20Control.pdf

[24] CAMTECH, Introductory Handbook on Communications Based Train Control (CBTC), CAMTECH, Gwalior, India, 2021. https://rdso.indianrailways.gov.in/uploads/files/Introductory%20Handbook%20on%20CBTC.pdf

[25] Indian Railways, Signal and Telecom Publications – CBTC Handbook Index, RDSO, Lucknow, India. https://indianrailways.gov.in/railwayboard/uploads/directorate/eff_res/camtech/S&T%20Engineering/YearWise/3_An%20Introductory%20Handbook%20on%20CBTC_April%202021.pdf

[26] CENELEC, EN 50129: Railway Applications – Safety-related Electronic Systems for Signalling, 2003. https://standards.iteh.ai/catalog/standards/clc/42c2dcf7-c764-45af-b4a7-a015ecfff75d/en-50129-2003

[27] CENELEC, EN 50126 / EN 50128 / EN 50129 – Railway Applications RAMS Overview, European Standards, 2025. https://european-standards.com/top-european-standards/n-50126-en-50128-en-50129-railway-applications/

[28] IZP Institute, EN 50126 Railway RAMS Standard: Specification, Verification and Management, IZP, 2024. https://www.izp.de/en-50126-specification-demonstration-rams-reliability-availability-maintainability-safety-case/

[29] IEC / Perforce, What Is IEC 61508? Determining Safety Integrity Levels (SILs), 2019. https://www.perforce.com/blog/qac/what-iec-61508-safety-integrity-levels-sils

[30] Emerson Automation Solutions, Safety Integrity Level (SIL) – IEC 61508/61511, white paper. https://www.emerson.com/documents/automation/technical-white-paper-safety-integrity-level-sil-en-71898.pdf

[31] IEC / CENELEC, EN IEC 62290-3: Urban Guided Transport Management and Command/Control Systems – Part 3: Functional Requirements for ATS, 2025. https://standards.iteh.ai/catalog/standards/clc/0b1e67f6-4147-4399-998f-b791bc1071e7/en-iec-62290-3-2025

[32] ERA, Safety Requirements for the Technical Interoperability of ETCS (Subset-091), European Union Agency for Railways, latest version. https://www.era.europa.eu/system/files/2023-01/sos3_index027_-_subset-091_v360.pdf

[33] Terada et al., Digital Automatic Train Control System for the Shinkansen Lines of East Japan Railway Company, Computers in Railways IV, WIT Press, 2002. https://www.witpress.com/Secure/elibrary/papers/CR02/CR02009FU.pdf

[34] S. Kawamura et al., A Review of the Japanese Train Control Systems, International Journal of Engineering and Applied Sciences, 2017. https://www.ijeas.org/download_data/IJEAS1002006.pdf

[35] TechScience Press, Real Time Control System for Metro Railways Using PLC & SCADA, Int. J. of Innovative Computing, Information and Control, vol. 35, no. 2, 2022. https://www.techscience.com/iasc/v35n2/48891

[36] ACM / Springer, PLC and SCADA-based Real Time Monitoring and Train Control, journal article, 2022. https://dl.acm.org/doi/abs/10.1007/s11277-022-10109-1

[37] M. Patnaik et al., Railway SCADA Monitoring and Control, International Research Journal of Engineering and Technology (IRJET), vol. 11, no. 9, 2024. https://www.irjet.net/archives/V11/i9/IRJET-V11I9100.pdf

[38] J. Li et al., Developing CBTC System Safety Requirement Hierarchy, IEEE Access / PMC, 2024. https://pmc.ncbi.nlm.nih.gov/articles/PMC11154601/