

Optimization of Workforce Continuity and Financial Risk Management Strategies to Mitigate Construction Delays

A Proposed Daytime 2-Shift Cyclic Model (2S-DWCM) with RERA Escrow Compliance for Urban Real Estate Projects

Tapas Gorai
Dept. of Project
Engineering and
Management
Jharkhand University of
Technology
Ranchi, Jharkhand, India

Dr. Ram Singh
Assistant Professor,
Dept. of Mechanical
Engineering
Jharkhand University of
Technology
Ranchi, Jharkhand, India

Dr. Pravir Kumar
Assistant Professor,
Dept. of Mechanical
Engineering
Jharkhand University of
Technology
Ranchi, Jharkhand, India

Dr. Ramesh Murmu
Assistant Professor,
Dept. of Mechanical
Engineering
Jharkhand University of
Technology
Ranchi, Jharkhand, India

Abstract - Schedule overruns in urban building construction across developing Indian tier-2 regions present recurring operational and commercial challenges. Conventional schedule crashing—primarily extended single-crew overtime or ad-hoc night shifts—consistently leads to physical fatigue, efficiency degradation, high incident rates, and local noise disputes. Concurrently, cash-flow diversions lead to vendor delivery suspensions and labor strikes. This study develops and validates an integrated operational and statutory framework: the 8-Hour × 2-Shift Dedicated Workforce Continuity Model (2S-DWCM) coupled with fund ring-fencing under Section 4(2)(l)(D) of the Real Estate (Regulation and Development) Act, 2016 (RERA). The operational system splits site execution into two discrete 8-hour daytime shifts (Shift 1: 06:00–14:00 and Shift 2: 14:00–22:00) with a mandatory 30-minute structured handover, followed by an 8-hour Night Shutdown (22:00–06:00). Individual labor duty is strictly held to 8 hours per day. The nocturnal shutdown enables undisturbed concrete hydration pursuant to Indian Standard IS 456:2000 and aligns with the Noise Pollution (Regulation and Control) Rules, 2000. Empirical validation was performed using field data from the Aparajita Sports City project in Hotwar, Ranchi, alongside a structured survey of 50 construction professionals (N = 50). Relative Importance Index (RII) analysis identified Workforce Continuity & Retention (RII = 0.788) and Systematic Manpower Planning (RII = 0.784) as the leading operational drivers to control project delays. Productivity assessments demonstrate that 2S-DWCM maintains crew efficiency at 0.4625 units/LH across a 16-hour daily production window, completely avoiding productivity loss observed in single-crew 12-hour overtime models.

Keywords - Construction Delay, Workforce Continuity, 2S-DWCM, Shift Handover, Concrete Hydration Window, RERA Escrow, Relative Importance Index (RII), Labour Productivity.

INTRODUCTION

The construction sector constitutes approximately 8% of India's GDP and is the second-largest employer after agriculture. Rapid urbanization in state capitals like Ranchi, Jharkhand, has accelerated investments in high-rise residential complexes and commercial projects. However, site delivery

remains constrained by recurring delays. In Critical Path Method (CPM) networks, delays in predecessor activities propagate through downstream trades, triggering substantial schedule overruns. When behind schedule, site management conventionally resorts to single-crew extended overtime (10–14 hours) or night work. These measures produce severe worker fatigue, drop labor efficiency by over 15%, elevate accident frequencies, and disturb fresh concrete setting mechanics. Nocturnal work also triggers municipal violations under the Noise Pollution Rules, 2000. Financially, diversion of project capital causes wage arrears, leading to labor strikes. The 2S-DWCM integrated with statutory RERA escrow mechanisms resolves these challenges by establishing an ergonomic 16-hour daytime active window.

RESEARCH AIM AND OBJECTIVES

The overarching aim of this research is to formulate and evaluate an integrated 8-Hour × 2-Shift Daytime Workforce Continuity Model (2S-DWCM) featuring an 8-hour nocturnal shutdown and RERA financial escrow governance to eliminate endemic building construction delays in developing urban centers such as Ranchi, Jharkhand. The specific research objectives are:

1. To identify, evaluate, and prioritize primary labor-related and financial delay drivers in urban Indian building construction.
2. To structure an operational 16-hour daytime working framework operating from 06:00 to 22:00 utilizing two discrete 8-hour labor crews.
3. To establish a formalized, checklist-driven inter-shift handover procedure between Shift 1 and Shift 2 to eliminate communication losses.
4. To evaluate the concrete hydration mechanics and acoustic compliance benefits provided by an 8-hour complete night shutdown (22:00 to 06:00).

5. To synthesize mathematical formulations quantifying physical output per labor-hour, direct cost trade-offs, and relative factor rankings.

6. To integrate the 70% statutory separate account mechanism under RERA Section 4(2)(l)(D) into monthly site labor wage and procurement protection.

Research questions and hypotheses

This study addresses key operational questions:

- (i) What are the dominant labor and financial drivers causing building construction delays in developing urban centers?
- (ii) Can a two-shift daytime model extend daily site production to 16 hours without exceeding individual 8-hour fatigue thresholds?
- (iii) How does an 8-hour nocturnal shutdown enhance concrete hydration integrity and statutory environmental compliance?

To evaluate these questions, three core hypotheses were formulated and tested:

- Hypothesis 1 (H1): Workforce continuity and long-term retention have a significant positive relationship with project schedule reliability.
- Hypothesis 2 (H2): Deploying two independent, dedicated 8-hour crews prevents the efficiency drop-offs typically observed during single-crew extended overtime.
- Hypothesis 3 (H3): Cash-flow ring-fencing under statutory RERA escrow mechanisms significantly mitigates material procurement suspensions and site labor strikes.

LITERATURE REVIEW

Construction delays stem from interdependent systemic causes including planning flaws, financial constraints, and supply chain bottlenecks [1, 4]. Patil and Nagarajan [2] observed that Indian construction research predominantly investigates large transportation corridors rather than regional urban building infrastructure. In shift planning, Jun and El-Rayes [15] demonstrated that multiple shifts can optimize project durations but introduce fatigue and managerial complexity. Hanna et al. [16] showed that shift execution can alter productivity between -11% and +17%. Udasi and Darade [14] established that RERA governance significantly enforces completion accountability. While individual factors have been evaluated, current literature lacks a practical model integrating dedicated labor continuity, controlled daytime shifts, nocturnal concrete hydration, and RERA escrow fund isolation.

Identification of Specific Research Gaps

Although construction delays have been extensively evaluated across global literature, existing studies present critical omissions when applied to regional urban building projects:

1. Gap in Dedicated Workforce Continuity: Most delay management literature evaluates labor shortages retrospectively. Conventional projects rely on ad-hoc daily wage mobilization, causing severe workforce turnover and repeated on-site learning curves. A proactive model retaining dedicated crews throughout project phases remains unexplored.

2. Gap in Shift Allocation versus Technical Setting Mechanics: While multi-shift scheduling has been studied analytically, literature rarely correlates shift schedules with biochemical concrete hydration requirements under Indian Standard IS 456:2000 and statutory night noise ceilings under the Noise Pollution Rules, 2000.

3. Gap in Worker Welfare and Productivity Integration: Worker welfare facilities (on-site rest rooms, nutritional support, and fatigue mitigation) are traditionally treated as human resource functions rather than direct mathematical determinants of site schedule reliability.

4. Gap in Statutory RERA Integration: Existing studies evaluate RERA purely as a regulatory compliance framework rather than an operational project cash-flow risk mitigation instrument to protect on-site labor liquidity.

Novelty of the Present Study

The novelty of this research lies in establishing an integrated operational and financial governance framework: the 2S-DWCM-RERA model. It bridges the gap between field execution and statutory accountability by synchronizing two dedicated 8-hour labor crews (maintaining individual worker fatigue thresholds), a 30-minute structured handover protocol, a mandatory 8-hour nocturnal concrete setting shutdown, and statutory fund ring-fencing under RERA Section 4(2)(l)(D).

RESEARCH METHODOLOGY

This research applies a mixed-methods design. Empirical observations were conducted during an eight-week research internship (January–March 2026) at the Aparajita Sports City township project in Hotwar, Ranchi, executed by Abhishek Singh Rathaur Construction Pvt. Ltd. A structured Likert-scale survey was administered to $N = 50$ construction professionals in Jharkhand, comprising Project Managers (30%), Site Supervisors/Engineers (30%), Contractors (20%), and Structural Consultants/Quantity Surveyors (20%). The Relative Importance Index and labour productivity was calculated as:

$$RII = \frac{\sum W}{A \times N} = \frac{1(n_1) + 2(n_2) + 3(n_3) + 4(n_4) + 5(n_5)}{5 \times N}$$

Where W is the respondent weighting (1 to 5, where 1 = Strongly Disagree to 5 = Strongly Agree), $A = 5$ is the maximum scale weight, and $N = 50$.

$$\text{Labour Productivity} = \frac{Q_j}{LH_j}$$

Where Q_j = Physical units of construction completed during shift j (e.g., m^3 concrete, m^2 formwork, units of masonry). LH_j = Total labour-hours expended in shift j .

THE 2S-DWCM OPERATIONAL ARCHITECTURE

The 2S-DWCM divides site operations into two 8-hour daytime shifts and an 8-hour nocturnal shutdown: Shift 1 (06:00 – 14:00): Handled by Crew A for primary structural tasks, formwork, rebar placing, and major concrete pouring. Inter-Shift Handover (13:30 – 14:00): A 30-minute structured

overlap where outgoing and incoming supervisors verify progress, structural integrity, material quantities, and safety logs. Shift 2 (14:00 – 22:00): Handled by Crew B for secondary masonry, MEP conduits, and material staging for next morning. Night Shutdown (22:00 – 06:00): Total site cessation. Under IS 456:2000, initial setting occurs within 30–90 minutes and final setting within 10 hours; the 8-hour nocturnal quiet period ensures vibration-free concrete hydration while complying with the Noise Pollution Rules, 2000 (day limit: 06:00–22:00). RERA Escrow Ring-Fencing: Under Section 4(2)(l)(D) of RERA, 70% of buyer collections are deposited into a dedicated bank account, requiring tripartite certification (Engineer, Architect, CA) to disburse funds strictly for labor wages and materials.

DATA ANALYSIS AND DISCUSSION

Survey analysis shows that Workforce Continuity & Retention (RII = 0.788) and Systematic Manpower Planning (RII = 0.784) rank highest among delay mitigation drivers, followed by Shift Coordination (RII = 0.776) and Liquidity Security (RII = 0.772).

Productivity Formulations:

For a standard 10-worker crew, Shift 1 produces 38 units over 80 labor-hours ($P1 = 0.4750 \text{ units/LH}$). Shift 2 yields 36 units over 80 labor-hours ($P2 = 0.4500 \text{ units/LH}$). Combined daily output reaches 74 units over 160 labor-hours ($P = 0.4625 \text{ units/LH}$). In contrast, a 12-hour single-crew overtime regime drops productivity to 0.4000 units/LH (a 15.8% decline) due to physical exhaustion.

Deconstructing the Crashing Fallacy: Doubling daily site operating hours from 8 to 16 does not halve project duration by 50% (e.g., 180 days to 90 days). Concrete curing under IS 456:2000 requires 7 to 14 days before stripping formwork regardless of manpower, and congested work-fronts cause trade stacking. 2S-DWCM achieves a realistic net schedule reduction of 20% to 35%.

CONCLUSION

Workforce continuity and statutory escrow protections resolve the root causes of urban construction delays. The 2S-DWCM system sustains labor efficiency across 16 active hours while limiting individual worker duty to statutory 8-hour limits. The mandatory 8-hour nocturnal shutdown guarantees structural concrete integrity and environmental noise compliance. Site managers should maintain independent crew rosters, enforce mandatory signed handover sheets, and stage evening materials during Shift 1.

A. Technical and Managerial Recommendations

Based on the validated 2S-DWCM framework, the following managerial protocols are recommended for urban project execution:

1. Enforcement of Strict Crew Segregation: Site administration must maintain independent duty rosters for Crew A and Crew B. Individual workers must not be assigned consecutive shifts to avoid fatigue-induced accidents and productivity drops.

2. Mandatory Handover Documentation: Shift 2 operations should only commence upon mutual sign-off of the

standardized Handover Verification Sheet by both outgoing and incoming site engineers.

3. Alignment of Concreting with Hydration Windows: Major structural pours must be scheduled during Shift 1 or early Shift 2, allowing the 8-hour nocturnal shutdown (22:00 to 06:00) to serve as an undisturbed setting period pursuant to IS 456:2000.

4. Implementation of Proactive Material Staging: Shift 1 must ensure that all aggregates, reinforcement bars, and mortar mixes required for Shift 2 are staged at the work-front prior to 14:00, circumventing evening supply chain shutdowns.

5. Integration of Statutory Escrow Governance: Project developers must maintain disciplined compliance with RERA Section 4(2)(l)(D) by establishing dedicated project escrow accounts to ring-fence wage disbursements and supplier payments.

6. Adoption of Objective Delay Analysis Methods: Standard public and commercial contracts should mandate Time Impact Analysis (TIA) under the SCL Delay and Disruption Protocol rather than relying on subjective engineer discretion.

B. Limitations and Future Scope of Research

While this study validates the operational efficiency of the 2S-DWCM model, certain limitations provide avenues for future inquiry:

- Multi-Regional Validation: The primary empirical survey (N = 50) was conducted within the Ranchi region; subsequent research should expand empirical validation across tier-1 and tier-3 urban centers in India.

- BIM and AI-Driven Shift Allocation: Future research should investigate the integration of Building Information Modeling (BIM) with genetic algorithms to dynamically schedule crew handovers and detect work-front spatial clashes in real time.

- Physiological Fatigue Monitoring: Field studies incorporating wearable biometric sensors could be conducted during extreme summer temperatures in Eastern India to monitor worker heart rate, body temperature, and hydration levels under two-shift regimes.

REFERENCES

- [1] Fernández, L., & Müller, H. (2026). Construction and engineering management factors causing schedule delays in small road projects: A mini-systematic review. *International Journal of Civil Engineering and Construction*, 7(1), 1–5. DOI: 10.22271/27078329.2026.v5.i1a.60.
- [2] Patil, S., & Nagarajan, K. (2026). Critical analysis of project delays in building construction sector in the Indian context: A comprehensive review. In P. Goyal et al. (Eds.), *Proceedings of the Conference on Technologies for Future Cities (CTFC 2025)*, Atlantis Highlights in Sustainable Development, 7, 396–406. DOI: 10.2991/978-94-6239-650-0_28.
- [3] Ngcobo, S., & Pilane, M. (2026). Project management practices and schedule control mechanisms in public infrastructure projects. *Journal of Civil Project Management*, 18(2), 112–126.
- [4] Youssef, M., Gab-Allah, A., Hagra, O., & Bahader, I. (2025). Factors affecting delays in oil and gas construction projects. *Scientific Reports*, 15, 44655. DOI: 10.1038/s41598-025-31645-3.
- [5] Gómez-Cabrera, A., León, L. C., Lopez, M. L., & Torres, A. (2025). Analyzing time and cost deviations in educational infrastructure projects: A data-driven approach using Colombia's public data platform. *Buildings*, 15(19), 3505. DOI: 10.3390/buildings15193505.

- [6] Mohanty, G., & Rai, G. (2025). Delays, disruptions, and diminished margins: Reassessing loss claims in Indian construction law. *National Law School of India Review*, 36(1), 45–68. DOI: 10.55496/GWKE5324.
- [7] Karale, Y. A., Sajane, A. S., Patil, S. K., & Desai, D. B. (2025). Delays in construction projects: Causes, effects, and mitigation — A thematic literature review. *International Journal of Scientific Research in Engineering and Management*, 9(11), 104–115. DOI: 10.55041/IJSREM54312.
- [8] Ates, M. N., Turkoglu, H., Damci, A., & Demirkesen, S. (2025). Strategies for delay mitigation in construction projects: A systematic review. 4th International Civil Engineering & Architecture Conference, Trabzon, Türkiye. DOI: 10.31462/icearc2025_ce_mng_025.
- [9] Alhawtmeh, O. S., Riaz, S. R. M., & Al Momani, T. A. K. (2025). Analysis of supply chain management in delay factors and their impact on construction projects in Jordan: A case study of road projects. *Journal of Cultural Analysis and Social Change*, 10(3), 81–88.
- [10] Memon, M., Memon, A. H., Khahro, S. H., & Javed, Y. (2023). Investigation of project delays: Towards a sustainable construction industry. *Sustainability*, 15(2), 1457. DOI: 10.3390/su15021457.
- [11] Araya, F. (2021). Modeling working shifts in construction projects using an agent-based approach to minimize the spread of COVID-19. *Journal of Building Engineering*, 41, 102413. DOI: 10.1016/j.job.2021.102413.
- [12] Yaseen, Z. M., Hasan Ali, Z., Salih, S. Q., & Al-Ansari, N. (2020). Prediction of risk delay in construction projects using a hybrid artificial intelligence model. *Sustainability*, 12(4), 1514. DOI: 10.3390/su12041514.
- [13] Kabre, C., & Kumar, P. (2019). Delay Analysis Methods (DAMs) in construction contracts in India. *Bulletin of the South Ural State University. Series Construction Engineering and Architecture*, 19(4), 52–59. DOI: 10.14529/build190406.
- [14] Udasi, A. P., & Darade, M. M. (2018). Delays in construction projects: Causes, effects and impacts of RERA. *International Journal of Research and Technology Innovation*, 3(7), 245–252.
- [15] Jun, D. H., & El-Rayes, K. (2010). Optimizing the utilization of multiple labour shifts in construction projects. *Automation in Construction*, 19(2), 109–119. DOI: 10.1016/j.autcon.2009.12.015.
- [16] Hanna, A. S., Chang, C.-K., Sullivan, K. T., & Lackney, J. A. (2008). Impact of shift work on labour productivity for labour intensive contractor. *Journal of Construction Engineering and Management*, 134(3), 197–204. DOI: 10.1061/(ASCE)0733-9364(2008)134:3(197).
- [17] Central Pollution Control Board / Government of India. (2000). *The Noise Pollution (Regulation and Control) Rules, 2000*. Ministry of Environment and Forests, New Delhi, India.
- [18] Bureau of Indian Standards. (2000). *IS 456:2000 – Plain and Reinforced Concrete – Code of Practice (Fourth Revision)*. Bureau of Indian Standards, New Delhi, India.