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Article

Identifying and Ranking Mitigation Measures for Delay Factors in Metro Rail Transit Systems: An Industrial Management Perspective from India

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Abstract: This study identifies and ranks mitigation measures for delay factors affecting Metro Rail Transit System (MRTS) projects in India, framing delay mitigation as an industrial management and information-coordination problem rather than a purely technical construction issue. Delay factors are grouped under five operational categories — labour, equipment, material, technical, and finance — and each category is paired with a set of candidate mitigation measures drawn from industry practice. Data were collected from 107 MRTS professionals identified through snowball sampling, comprising client-side (38.3%), contractor-side (33.6%), and consultant-side (28.0%) respondents with varied levels of field experience across 93 distinct designations. Respondents indicated which mitigation measures they consider effective for each delay category and estimated the percentage of category-specific delay that these measures can eradicate. The findings show that proper labour management prior to activity scheduling (88.8%), proper resource planning for materials (74.8%), expediting organizational decision-making (83.2%), timely maintenance of equipment (69.2%), and ensuring accurate cost estimation during tendering (70.1%) are the most widely endorsed measures within their respective categories. Weighted mean perceived-effectiveness scores range from 58.1% (equipment) to 66.5% (labour) across categories. The results indicate that managerial and information-coordination measures are consistently endorsed above purely technological ones, a finding relevant to industrial management applications seeking to prioritize low-cost, high-adoption decision-support interventions in large infrastructure projects.
Keywords: mitigation measures, MRTS, industrial management, decision support, construction delay, information systems, India

1. Introduction

MRTS projects in India have become central to the country's urban infrastructure expansion, yet their delivery record remains marked by persistent schedule and cost deviations. Ministry of Statistics and Programme Implementation data placed 458 major infrastructure projects over budget by more than ₹5.71 lakh crore as of May 2024, with over 800 projects running behind schedule and an average slippage of roughly three years. Metro rail corridors are not exempt from this pattern: Mumbai Metro Line 3 alone saw its sanctioned cost rise from ₹23,136 crore to ₹37,276 crore following repeated schedule extensions, and comparable overruns have been reported across Delhi, Bengaluru, Jaipur, Chennai, Kochi, and Hyderabad metro projects.

While delay factors themselves have been extensively catalogued in prior research, the mitigation side of this literature remains comparatively underdeveloped. Arantes and Ferreira [1] demonstrated that delay mitigation measures in construction projects can be structured through interpretative modeling to reveal which interventions carry the greatest driving influence over others, moving the discussion beyond simple factor lists toward actionable hierarchies. Bhosale, Yadav, and Ambekar [2] extended this further by linking specific remedial measures to accountable stakeholders and grounding them in project management body of knowledge principles, arguing that mitigation is only operationally useful when tied to a responsible party and a recognized management framework. In a megaproject-specific context, Oyegoke and Al Kiyumi [3] examined delay mitigation in the Sultanate of Oman and

found that the practical adoption of mitigation strategies by industry professionals often diverges from what academic literature prescribes, underscoring the value of field-validated, practitioner-endorsed measures over purely theoretical ones. Obondi [4] similarly observed that construction project management research has concentrated heavily on risk identification and assessment while relatively neglecting the control and monitoring processes that determine whether identified risks are actually managed in practice. Zadeh and Qayoumi [5] demonstrated the applicability of structured, stakeholder-stratified questionnaires for ranking delay-related factors in EPC construction contexts, distributing their instrument to owner, consultant, and external respondent groups in Iranian nonindustrial building projects.

Banobi and Jung [6] compared owner-side and contractor-side perceptions of delay mitigation in Tanzanian power construction projects, finding that both stakeholder groups converged on measures such as close project supervision, capacity-building training, and proper logistics management in successful projects, but diverged sharply once time overruns exceeded ten percent. Böhme, Escribano, Heffernan, and Beazley [7] examined declining productivity in the Australian mid-rise residential construction sector and identified labour-focused mitigation measures as the interventions most consistently endorsed by site managers. Bajjou and Chafi [8] surveyed Moroccan construction professionals and found that timely equipment maintenance and accurate material estimation were rated among the most effective preventive measures against schedule delay.

Beyond managerial measures, a distinct stream of literature frames delay mitigation as an information systems and industrial management problem, which motivates the framing adopted in this study. Pérez, Avila, and Sánchez [9] found that Building Information Modeling (BIM) uses such as 4D construction planning and design review, combined with Lean tools such as the Last Planner System, substantially influence the mitigation of schedule delay in building projects. Lee, Yang, Lim, Hong, and Kim [10] and Lee, Kim, and Yu [11] demonstrated that BIM- and ontology-based information systems improve the accuracy and speed of cost-related decision-making in the early design phase, directly relevant to the finance-category mitigation measures examined in this study. Sacks, Koskela, Dave, and Owen [12] established the theoretical basis for integrating Lean production principles with BIM-based information flow in construction management, arguing that mitigation effectiveness depends on how efficiently information is coordinated across project stakeholders rather than on any single technology in isolation. Ali and colleagues [13, 14] developed centralized, BIM-based information repositories for recording and visualizing construction delay claims, illustrating a concrete industrial management application in which structured information systems directly support delay mitigation and dispute reduction. Darko, Chan, Ameyaw, Owusu, Pärn, and Edwards [15] reviewed the application of the Analytic Hierarchy Process as a decision-support technique in construction management, noting that multi-criteria decision-support tools are most frequently applied to risk management and sustainability problems — a methodological precedent relevant to structuring practitioner-endorsed mitigation measures into a decision-useful ranking, as undertaken in this study.

Taken together, this literature indicates that mitigation measures are context- and stakeholder-dependent, that certain managerial interventions recur as high-value measures across diverse project settings, that information systems and decision-support tools increasingly mediate how mitigation measures are identified and applied, and that field-validated, practitioner-endorsed data remain comparatively scarce for Indian MRTS projects specifically. This study addresses that gap by identifying which mitigation measures MRTS professionals across client, consultant, and contractor roles already consider effective against delay factors in five operational categories — labour, equipment, material, technical, and finance — and reporting their aggregate level of endorsement across a sample of 107 respondents, offering a field-validated reference point for industrial and project managers seeking low-cost, high-endorsement interventions.

2. Materials and Methods

This study adopts a descriptive, field-survey-based methodology to identify and rank mitigation measures perceived as effective against MRTS delay factors, without modelling causal or predictive relationships between variables.

2.1 Instrument

A structured questionnaire was administered through Google Forms, comprising background questions on respondent designation, years of experience, and stakeholder affiliation, followed by five category-specific question blocks corresponding to labour, equipment, material, technical, and finance-related delay factors. Within each block, respondents were asked to select, from a fixed list of candidate mitigation measures, all measures they considered effective against the delay factors listed for that category, and subsequently to indicate on a five-point ordinal scale (20%, 40%, 60%, 80%, 100%) the percentage of category-specific delay they believed these measures could

collectively eradicate. The category presented to respondents as "Communication and scope change" in the original survey instrument is reported in this study as "Technical" for terminological consistency with the author's broader research programme; the underlying survey items are unchanged, and the relabeling is nominal only.

2.2 Sampling

Given the absence of a centralized public directory of MRTS professionals in India, probability-based sampling was not feasible. Respondents were therefore identified through snowball sampling, beginning with professionals known to the researcher through prior project engagements and MRTS industry contacts, who subsequently referred additional eligible respondents. A total of 107 valid responses were retained for analysis. The sample comprised client-side (38.3%), contractor-side (33.6%), and consultant-side (28.0%) professionals, with experience levels ranging from under five years (16.8%) to more than fifteen years (21.5%), and spanned 93 distinct designations, indicating broad occupational diversity within the MRTS sector.

2.3 Data Analysis

Two descriptive metrics were computed for each delay category. First, the endorsement frequency of each individual mitigation measure was calculated as the proportion of the 107 respondents who selected that measure, providing a within-category ranking of practitioner-endorsed interventions. Second, a weighted mean perceived-effectiveness score was computed for each category by treating the five ordinal percentage brackets (20, 40, 60, 80, 100) as interval midpoints and calculating the frequency-weighted average across all 107 responses. This study does not apply inferential statistical testing given its aggregate, descriptive scope; the resulting rankings and scores should be interpreted as a practitioner-endorsed snapshot rather than a causally validated model.

3. Results

Table 1 presents the endorsement frequency of each mitigation measure within its respective delay category, ranked in descending order of respondent endorsement.

Table 1. Endorsement Frequency of Mitigation Measures by Category (n = 107)

Category	Mitigation Measure	Respondents Endorsing (n, %)
Labour	Proper labour management prior to activity scheduling	95 (88.8%)
Labour	Swift replacement and training for skilled labour	74 (69.2%)
Labour	Safety measures and equipment for labour	64 (59.8%)
Equipment	Timely maintenance of equipment	74 (69.2%)
Equipment	Contractor arranges sufficient equipment; client grants tender accordingly	73 (68.2%)
Equipment	Escalating issue to the organization	36 (33.6%)
Material	Proper resource planning	80 (74.8%)
Material	Correct estimate of material	68 (63.6%)
Material	Ensuring swift and timely logistics of material	44 (41.1%)
Technical	Speeding up organizational decision-making	89 (83.2%)
Technical	Implementing BIM and IoT tools	35 (32.7%)
Finance	Ensuring proper estimate during tendering	75 (70.1%)
Finance	Clearly working out finances for the project period	65 (60.7%)
Finance	Timely payment to contractors/subcontractors	36 (33.6%)
Finance	Scope of work clearly defined	33 (30.8%)

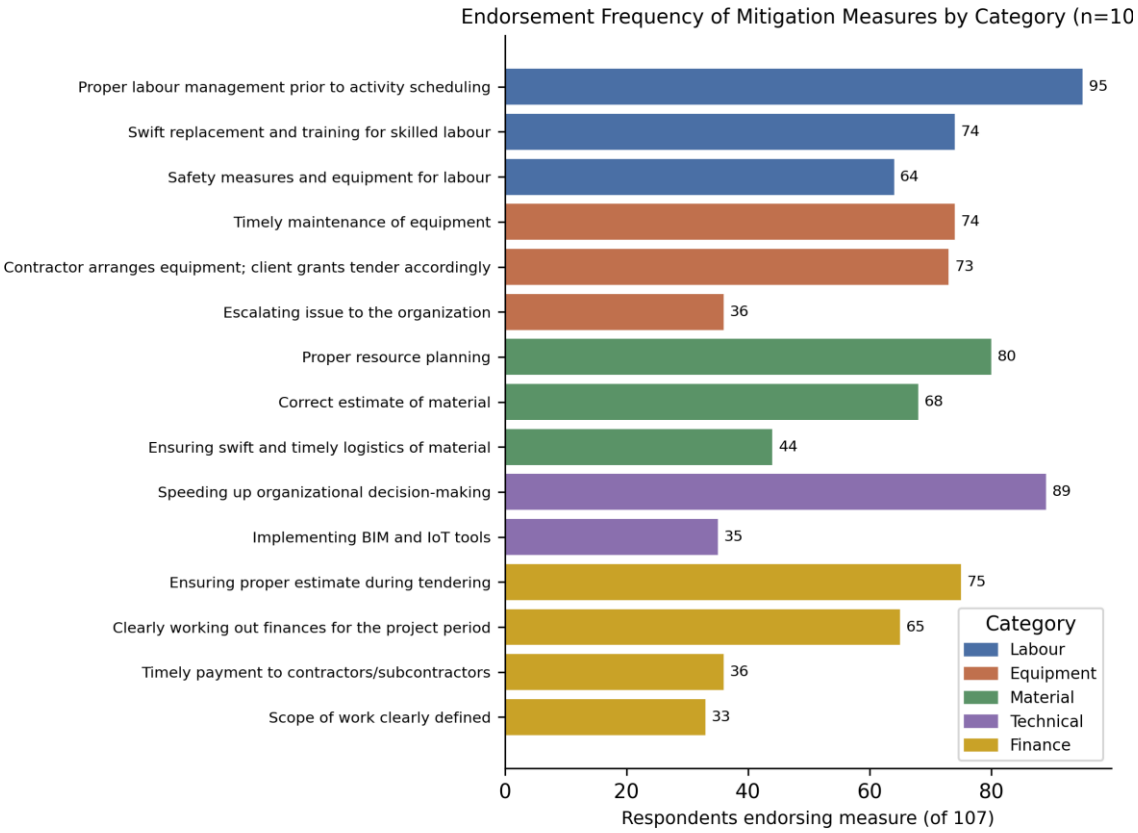

Fig. 1. Endorsement Frequency of Mitigation Measures by Category (n = 107)

Table 2 reports the weighted mean perceived-effectiveness score for each delay category, computed from the five-point ordinal effectiveness distribution.

Table 2. Weighted Mean Perceived Effectiveness of Mitigation Measures by Category (n = 107)

Category	Weighted Mean Perceived Effectiveness (%)
Labour	66.5
Equipment	58.1
Material	62.2
Technical	63.7
Finance	63.9

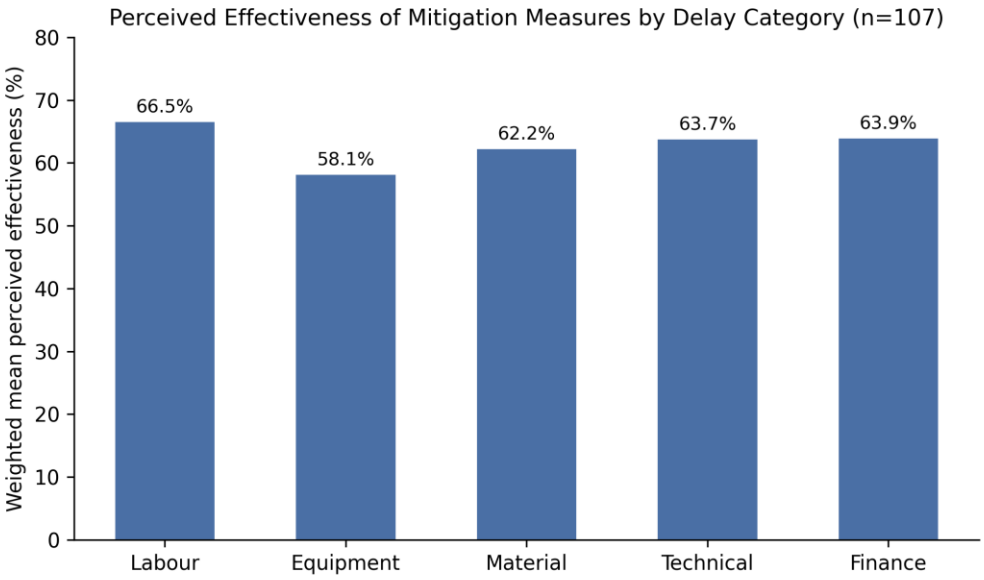

Fig. 2. Weighted Mean Perceived Effectiveness of Mitigation Measures by Delay Category (n = 107)

Labour recorded both the highest single-measure endorsement (proper labour management prior to activity scheduling, 88.8%) and the highest weighted effectiveness score (66.5%) among the five categories. Equipment recorded the lowest weighted effectiveness score (58.1%), despite two of its three measures being endorsed by more than two-thirds of respondents. The technical category exhibited the widest gap between its two measures (83.2% versus 32.7%), indicating that organizational decision-making speed is regarded as substantially more consequential than technology adoption (BIM/IoT) for mitigating technical delay.

4. Discussion

The aggregate ranking reported here is broadly consistent with international literature on delay mitigation, while also surfacing patterns specific to the Indian MRTS context. The strong endorsement of proper labour management prior to activity scheduling echoes Böhme et al.'s [7] finding that workforce planning and supervision continuity, rather than reactive measures, are what site-level managers regard as most effective against labour-driven delay. Similarly, the high endorsement of correct material estimation and proper resource planning parallels Bajjou and Chafi's [8] finding that preventive, planning-stage interventions outperform corrective ones in professional perception.

The wide gap observed within the technical category — between organizational decision-making speed (83.2%) and technology adoption via BIM/IoT (32.7%) — merits particular attention from an industrial management standpoint. This is consistent with Arantes and Ferreira's [1] structural finding that certain mitigation measures function as driving interventions whose influence extends beyond their immediate category, and with Sacks et al.'s [12] argument that mitigation effectiveness depends on how efficiently information is coordinated across stakeholders rather than on any single technology in isolation. Delayed organizational decisions can compound delay across labour, material, and equipment categories simultaneously, whereas technology adoption alone addresses a narrower band of technical inefficiency — suggesting that, within the Indian MRTS sector, practitioners currently perceive organizational and information-coordination reform as more consequential than digital-tool adoption in isolation, a finding that qualifies rather than contradicts the decision-support gains reported for BIM-based systems in Lee et al. [10, 11] and Ali et al. [13, 14].

Equipment recorded the lowest weighted effectiveness score despite reasonably high endorsement of individual measures, a pattern that may reflect the specialized and often imported nature of MRTS-specific equipment (tunnel boring machines, launching girders), where mitigation measures such as timely maintenance or contractual equipment-arrangement clauses can reduce but not eliminate equipment-driven delay. This is consistent with Bhosale et al.'s [2] argument that mitigation measures are only as effective as the stakeholder accountable for them is empowered to act.

Consistent with Oyegoke and Al Kiyumi's [3] observation that practitioner-endorsed mitigation frequently diverges from academic prescription, several of the most highly endorsed measures in this study — proper labour

management, organizational decision-making speed, and resource planning — are managerial and procedural rather than technological, suggesting that decision-support and information-management interventions of the kind reviewed by Darko et al. [15] may find more immediate industry acceptance in the Indian MRTS sector than standalone digital tools.

5. Conclusion

This study identified and ranked mitigation measures perceived as effective against MRTS delay factors across five operational categories, based on aggregate, field-survey data from 107 professionals spanning client, consultant, and contractor roles in the Indian MRTS sector. Proper labour management prior to activity scheduling, expedited organizational decision-making, and proper material resource planning emerged as the most widely endorsed measures overall, while equipment-related measures recorded comparatively lower perceived effectiveness despite reasonable endorsement levels.

From an industrial management standpoint, the findings suggest that managerial and information-coordination interventions currently command greater practitioner confidence than standalone technological tools, offering project managers, contractors, and policymakers a field-validated reference point for prioritizing low-cost, high-endorsement interventions.

This study is subject to several limitations. Effectiveness estimates are based on respondents' self-reported perceptions rather than measured project outcomes; the non-probabilistic snowball sampling approach limits statistical generalizability; this study reports aggregate findings only and does not examine variation across project phase, typology, ownership structure, or stakeholder role; and the cross-sectional data collection does not capture shifts in practitioner perception over time. Future research may extend this account by examining such stratified variation and by validating perceived effectiveness against measured project-level delay outcomes.

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