

Business Intelligence Dashboards for Construction Project Monitoring and Control: A Critical Review of Performance Measurement Frameworks, Platforms, and Implementation Practice

Jawed Khan Mohammad Khan Pathan¹(Anjuman-i-islam's Kalsekar Technical Campus, Panvel, Maharashtra, India), Prof. Tehsin Kazi²(Asst. Professor, Anjuman-i-islam's Kalsekar Technical Campus, Panvel, Maharashtra, India)

Abstract

Construction projects continue to record cost and time outcomes that fall short of their baseline commitments, and a recurring explanation across four decades of research locates the problem in weak feedback between site conditions and managerial decisions rather than in technical uncertainty alone. Business intelligence (BI) platforms, which convert dispersed operational records into interactive visual reports, have been advanced as a route to closing this feedback loop, yet the supporting evidence remains scattered across several research communities that seldom cite one another. This paper reviews forty-five peer-reviewed studies published between 1992 and 2024 spanning monitoring theory, earned value and earned schedule methods, key performance indicator (KPI) frameworks, BI adoption, dashboard design, and digital data capture, with the aim of assembling a coherent account of what is settled and what remains open in BI-enabled construction monitoring. The review is organised thematically and reads each strand critically, comparing its assumptions, methods, and boundary conditions rather than merely cataloguing findings. Five observations emerge. Monitoring scholarship has matured conceptually but has rarely produced tools that small and medium contractors can deploy. Earned schedule methods repair well-documented weaknesses of the classical schedule performance index while appearing only sparsely at the platform level. KPI research offers comprehensive indicator sets that are seldom integrated across cost, time, quality, safety, and resource dimensions inside a single interface. Studies of platforms such as Power BI and Tableau in construction are recent and dominated by single-dimension demonstrations. Data governance and input architecture, named repeatedly as the leading cause of monitoring system failure, attract far less attention than visualisation. The synthesis isolates six gaps and maps a corresponding research agenda, with emphasis on the low-digital-maturity settings that characterise construction in India and comparable emerging economies.

Keywords: Construction project monitoring; Business intelligence; Power BI; Earned value management; Earned schedule; Key performance indicators; Dashboard design; Digital transformation

Date of Submission: 15-09-2026

Date of Acceptance: 29-09-2026

I. Introduction

The construction sector accounts for a large share of national output and employment in most economies, and its delivery record has drawn sustained scholarly attention precisely because that record so often disappoints. Empirical surveys of infrastructure and building portfolios report cost growth and schedule slippage as the ordinary rather than the exceptional result [1], [2], [3]. Flyvbjerg and colleagues, examining 258 transport projects across twenty nations, found cost escalation in close to nine of every ten cases and attributed much of it to institutional and informational failures rather than to unforeseeable engineering difficulty [1]. Regional investigations from India, Saudi Arabia, Malaysia, and the Gaza Strip repeat the pattern and name deficient monitoring and reporting among the dominant contributory factors [2], [3], [4], [5]. The persistence of these findings across markets separated by decades and by very different institutional conditions signals a structural weakness in how construction organisations sense and respond to project performance.

The weakness that this body of work exposes is not a scarcity of data. A building project of moderate complexity generates thousands of records each week covering labour deployment, material movement, plant utilisation, inspection outcomes, financial transactions, and safety events. The difficulty lies in converting that volume into intelligence that reaches decision makers while the window for corrective action remains open. Records kept in handwritten diaries, disconnected spreadsheets, and periodic narrative reports tend to arrive late and in inconsistent formats, with the effect that no single participant holds a current and complete picture of project health at any given moment [6], [9]. Early web-based monitoring systems such as the project performance

monitoring system proposed by Cheung and colleagues recognised this fragmentation and attempted to centralise indicator reporting through a browser interface [9], yet adoption of such bespoke systems stayed low, in part because they demanded infrastructure and skills that most contractors lacked.

Business intelligence describes a family of software tools that aggregate data from heterogeneous sources, apply analytical transformations, and present the result through interactive dashboards accessible to non-specialist users [24]. Adoption in finance, manufacturing, healthcare, and retail moved quickly once data-driven decision making became a competitive requirement, but construction lagged, owing partly to the project-based and geographically dispersed nature of the work and partly to a site culture that has historically valued experience over measurement [25], [30]. Microsoft Power BI has become one of the most widely deployed BI platforms because it combines drag-and-drop authoring, native connectors to spreadsheets and databases, a formula language for analytical modelling, and low-cost cloud sharing. These attributes make it a plausible candidate for construction monitoring in organisations that cannot justify enterprise project management suites, and a small but growing literature has begun to test that proposition [27], [28], [29], [30].

Despite this activity, the knowledge relevant to BI-enabled construction monitoring sits in several communities that rarely engage with one another. Monitoring and control theory has developed in construction management journals. Earned value and earned schedule mathematics have advanced largely within project management and operations research outlets. Dashboard design principles come from information visualisation and human factors. Data capture and automation appear in construction informatics venues focused on building information modelling (BIM), the internet of things (IoT), and computer vision. A reader seeking to design or evaluate a BI monitoring solution must reconcile these separate conversations without much help from the existing literature, because few reviews cut across all of them.

This paper addresses that need through a critical thematic review guided by five questions. The first asks how monitoring theory has framed the data-to-decision problem and what solution requirements follow from that framing. The second examines which performance measurement methods are mature enough for platform implementation and where they still fall short. The third assesses the state of evidence on BI platforms, and Power BI in particular, in construction settings. The fourth considers how data capture, data governance, and dashboard design mediate monitoring success. The fifth identifies the gaps that remain, with attention to low-digital-maturity contexts, and derives a research agenda from them. The review draws on forty-five peer-reviewed sources and reads them comparatively rather than descriptively, weighing methods and boundary conditions so that the synthesis rests on evidence quality rather than on citation counts.

The remainder of the paper proceeds as follows. Section 2 describes the review method. Section 3 examines the theoretical foundations of construction monitoring and control. Section 4 reviews earned value and earned schedule methods. Section 5 surveys KPI frameworks. Section 6 treats BI and analytics in project environments, and Section 7 focuses on Power BI and comparable platforms in construction. Section 8 reviews digital data capture through BIM, IoT, and automated progress monitoring. Section 9 addresses dashboard design and human factors, and Section 10 considers monitoring in developing-economy contexts. Section 11 synthesises the evidence and isolates six research gaps. Section 12 sets out future directions, and Section 13 concludes.

II. Review Methodology

The review adopts a structured narrative approach rather than a fully quantitative systematic protocol, a choice suited to a field whose relevant literature is dispersed across construction management, project management, information systems, and construction informatics, and whose terminology is inconsistent across those domains. Source identification drew on Scopus, ScienceDirect, the ASCE Library, Web of Science, and Google Scholar, using combinations of terms covering the performance domain (project monitoring, performance measurement, project control, earned value, earned schedule, key performance indicators), the technology domain (business intelligence, dashboard, data visualisation, Power BI, Tableau, analytics), and the sector qualifier (construction, building, infrastructure). Backward and forward citation tracing on the most cited items supplemented the keyword search and recovered foundational works that predate the current terminology.

Inclusion favoured peer-reviewed journal articles and a small number of authoritative conference papers and monographs where these represent the primary reference for a concept. The publication window spans 1992 to 2024, a range chosen to capture the production-systems reframing of construction management at its start [6] and recent BI implementation studies at its end. Items were retained when they contributed to at least one of the five review questions and offered either empirical evidence, a methodological contribution, or a conceptual framework that later work has adopted. Purely promotional vendor material and studies without a construction or project-control connection were excluded. The final corpus comprises forty-five sources. Each was coded against the thematic structure used in Sections 3 to 10, with several sources mapped to more than one theme because their contributions cut across boundaries. Table 1 summarises the thematic distribution and the dominant method within each theme, which helps expose where the evidence base is thin.

Table 1. Thematic distribution of the reviewed corpus and dominant evidence type

Review theme	Sources	Dominant evidence type	Maturity
Monitoring and control foundations	8	Survey and case analysis of delay and overrun causes	High
Earned value and earned schedule	7	Analytical and longitudinal forecasting studies	High
KPI frameworks	6	Delphi, benchmarking, and framework synthesis	High
BI and analytics in projects	5	Adoption surveys and taxonomy building	Moderate
Power BI and BI platforms in construction	4	Single-case proofs of concept	Low
Digital data capture (BIM, IoT, vision)	7	Reviews and technical feasibility studies	Moderate
Dashboard design and human factors	3	Design theory and controlled comparison	Moderate
Developing-economy contexts	5	Regional surveys and utility modelling	Moderate

The distribution in Table 1 already carries an argument. The two most mature themes, monitoring foundations and earned value, concern what to measure and why it matters, whereas the themes that concern how a modern BI tool would actually deliver such measurement, platform implementation and dashboard design, rest on the thinnest and most recent evidence. The review returns to this imbalance in Section 11.

III. Foundations of Construction Project Monitoring and Control

Monitoring and control rank among the most heavily studied functions in construction management, and the literature has consistently found a wide gap between prescribed practice and site reality. Koskela reframed the field by arguing that construction management had inherited a transformation-oriented planning paradigm from manufacturing that suited neither the variability nor the flow characteristics of construction production [6]. The transformation-flow-value model that followed shifted analytical attention from the completion of discrete tasks to the continuous state of production flow, and it implied that useful monitoring must observe flow reliability rather than milestone attainment alone. Ballard operationalised this insight through the Last Planner System, whose percentage of plan completed metric measures short-interval commitment reliability and has been shown to reduce schedule variability where it is applied with discipline [7]. The dependence of the Last Planner System on manual look-ahead planning and physical tracking boards, however, creates a data capture problem that has proved awkward to reconcile with digital monitoring, a tension that later BI studies inherit rather than resolve [27].

A parallel stream sought to formalise what performance measurement in construction should encompass. Kagioglou and colleagues proposed a conceptual framework that balanced project results against the health of the processes and the organisation that produced them, drawing on the balanced scorecard logic then influential in general management [8]. The framework anticipated a recurring difficulty that the KPI literature would later confront, namely that outcome indicators report on performance only after it has occurred, whereas leading process indicators are harder to define and to collect but carry the diagnostic value that managers actually need. Cheung and colleagues translated indicator thinking into an early web-based monitoring system that tracked people, cost, time, quality, safety, and client satisfaction through a shared browser interface [9], and Nassar and AbouRizk later integrated multiple indicators into a single composite performance measure supported by a structured aggregation procedure [10]. Both works demonstrate that the ambition of integrated, multi-indicator monitoring predates modern BI platforms by more than a decade, which reframes recent dashboard studies as a change of delivery vehicle rather than of underlying goal.

The empirical literature on why projects underperform reinforces the case for stronger monitoring while also complicating it. Doloi and colleagues applied structural equation modelling to ninety-seven completed Indian projects and isolated poor communication, ineffective monitoring routines, and inadequate reporting among the most statistically significant contributors to schedule slippage [3]. Their result matters because it positions monitoring deficiency as a causal factor in its own right rather than as a mere symptom of broader mismanagement. Assaf and Al-Hejji catalogued seventy-three delay causes across seventy-three Saudi projects and found late material delivery, design change, and weak planning among the most frequently cited, all of which a responsive monitoring system is positioned to detect early [2]. Memon and colleagues, working in Malaysia, ranked inadequate monitoring not only as an independent driver of overrun but as an amplifier that worsened the impact of price shocks and cash flow stress, because slow information delayed the targeted response [4]. Enshassi and colleagues, studying the resource-constrained Gaza Strip, observed that experienced managers under severe uncertainty relied on a compact set of leading indicators rather than exhaustive trailing metrics, since the administrative burden of tracking many measures at once became counterproductive [5]. This last finding carries

a design implication that dashboard research has been slow to absorb, namely that indicator parsimony can matter more than indicator completeness when cognitive load is high.

Read together, the foundational literature supplies a clear requirements brief for any monitoring tool. It should observe flow and leading conditions, not only completed milestones. It should integrate several performance dimensions, because the causes of failure cut across them. It should deliver information fast enough to preserve the option of intervention. It should remain parsimonious enough to be usable under pressure. The gap that this literature leaves open is one of realisation rather than of specification, since these requirements have been articulated for years without a widely adopted, low-cost instrument that satisfies them in ordinary site conditions.

IV. Earned Value and Earned Schedule Methods

Earned value management (EVM) remains the most widely recognised quantitative framework for integrated cost and schedule control. It assigns a monetary value to completed work, the budgeted cost of work performed, and compares it against the budgeted cost of work scheduled and the actual cost of work performed to yield the cost performance index and the schedule performance index [11]. Fleming and Koppelman argued that the method succeeds as a management discipline rather than as a computational exercise, and that its value depends on organisational commitment as much as on arithmetic [11]. Anbari systematised the family of EVM measures and their extensions into forecasting, clarifying how index values translate into estimates of final cost and duration [12]. The durability of these contributions rests on a strong assumption that later authors have repeatedly interrogated, namely that the work breakdown structure to which planned values are assigned is granular and reliable enough for the indices to reflect real site conditions.

The most consequential critique of classical EVM concerns its schedule dimension. The schedule performance index expressed in cost units converges toward unity as a project nears its planned finish, regardless of whether the work is actually on time, an artefact that renders the metric misleading in exactly the late phases where schedule risk is greatest. Lipke and colleagues resolved this defect with the earned schedule method, which converts schedule performance into a time-based measure by locating the date on the baseline at which the accumulated planned value equals the current earned value [13]. The resulting time-based index and variance retain diagnostic meaning throughout the project life, and independent studies have confirmed the improvement [14]. Khamooshi and Golafshani pressed the point further with earned duration management, which decouples schedule measurement from cost data entirely so that cost distortions cannot contaminate the schedule signal [14]. The progression from schedule performance index to earned schedule to earned duration management illustrates a field correcting its own instruments, yet the practical uptake of these refinements has lagged the theoretical consensus, and implementations that embed earned schedule inside a live BI platform are notably rare.

Forecasting accuracy forms the second major thread. Narbaev and De Marco combined growth models with earned value indices to improve the estimate at completion, and their longitudinal analysis of infrastructure projects showed that such forecasts became reliable only after roughly a fifth of the work was complete, since sparse early data produce unstable projections [15]. Kim and colleagues examined how forecasts could be combined across methods to hedge the weaknesses of any single formula [17]. Vanhoucke evaluated the efficiency of project control itself, using simulated and empirical data to ask when EVM signals justify the effort of investigation, and found that control efficiency depends heavily on network structure and on the phase at which deviations arise [16]. These studies share a caution that dashboard designers ought to heed, namely that an automatically computed estimate at completion is not equally trustworthy at every stage, and that a monitoring interface which presents such a figure without conveying its provisional status in early phases risks encouraging premature decisions.

The collective message of the EVM literature is that the analytical machinery for integrated cost and schedule monitoring is mature, well validated, and ready for automation, subject to two conditions. The measurement of physical progress must be defined objectively enough to prevent estimator bias from entering the earned value, and the schedule dimension should adopt the earned schedule formulation rather than the flawed classical index. Both conditions are matters of implementation discipline rather than of unresolved theory, which locates the frontier for this theme squarely at the point where the mathematics meets a working platform.

V. Key Performance Indicator Frameworks

Systematic KPI development for construction gathered momentum in the late 1990s as industry bodies in the United Kingdom, Australia, and Hong Kong launched benchmarking programmes. Beatham and colleagues traced the British lineage to the Egan agenda and offered a critical appraisal that distinguished genuine performance indicators from measures that merely record activity, cautioning that many published KPIs describe outputs after the fact and so provide little scope for intervention [18]. Their distinction between lagging result indicators and leading perception or process indicators has structured much subsequent work and connects directly

to the flow-monitoring argument advanced in the production-systems literature [6]. Chan and Chan built a construction success framework through a Delphi study with fifty-five practitioners, separating objective indicators drawn from project records from subjective indicators requiring judgement [19]. The two-tier structure acknowledges that project success resists capture through quantitative metrics alone, a point Bassioni and colleagues reinforced by adapting excellence and balanced scorecard models to construction performance measurement [20].

Empirical benchmarking sharpened the understanding of how indicators relate to competitive outcomes. El-Mashaleh and colleagues applied data envelopment analysis to ninety-five Jordanian contractors and found that the most efficient firms were distinguished less by excellence on any single KPI than by consistency across profitability, schedule, safety, and quality [21]. This result carries a strong design implication, since it suggests that monitoring focused on one dimension can mislead, and that integrated multi-dimensional observation predicts firm success more reliably than any isolated measure. Costa and colleagues, reporting on cross-national benchmarking initiatives, documented the practical obstacles to consistent indicator definition and data comparability that undermine such programmes in practice [23], an obstacle that anticipates the data governance problems later identified as decisive for BI monitoring. Meng approached KPIs from a supply chain perspective and showed that relational indicators, covering information sharing, collaborative problem solving, and joint risk management, predicted project success more strongly than conventional cost and time metrics in a sample of collaborative UK projects [22]. The relational dimension sits almost entirely outside current construction dashboards, which points to a specific enrichment opportunity rather than a flaw in existing practice.

The KPI literature, taken as a whole, has produced richer and more validated indicator sets than construction monitoring tools typically implement. Several tensions persist. Comprehensive frameworks risk overwhelming users, which collides with the parsimony lesson from resource-constrained settings [5]. Subjective and relational indicators carry predictive value yet resist automation, since they cannot be computed from transaction records alone [19], [22]. Indicator definitions vary enough across studies to frustrate cross-project comparison [23]. A monitoring platform must resolve these tensions through selection and layering rather than by attempting to display everything, and the literature offers principles for that selection without prescribing a single canonical set, which leaves the design of an integrated, automatable, and parsimonious indicator suite as an open task.

VI. Business Intelligence and Analytics in Project Environments

The migration of business intelligence into project management has been mapped through adoption studies and maturity taxonomies. Delen and colleagues, working with financial ratio analysis, articulated a progression from descriptive analytics concerned with historical reporting, through diagnostic analytics oriented to root-cause identification, to predictive analytics that forecast future states [24]. The taxonomy travels well beyond finance and provides a useful yardstick for positioning construction monitoring tools, most of which operate at the descriptive and early diagnostic levels because the data maturity required for reliable prediction is seldom present on site. Hwang and colleagues surveyed construction firms in Singapore and found that scheduling software had achieved near-universal adoption while BI and analytics platforms remained confined to a small minority of firms, held back by cost, by the absence of standardised site data capture, and by a shortage of staff able to configure analytical tools [25]. Their diagnosis identifies the precise barriers that a low-cost, low-skill BI platform would need to lower, and it explains why the accessibility of a tool matters as much as its analytical depth.

Analytics applied to construction records has begun to demonstrate concrete value beyond reporting. Marzouk and Enaba applied text analytics to project correspondence and contract documents to surface risk and delay signals that structured indicators miss, showing that unstructured project data holds monitoring value that conventional metrics leave untapped [26]. Han and Golparvar-Fard examined the potential of large visual datasets combined with BIM for performance analytics, arguing that the imagery routinely captured on sites could feed progress and quality analysis if the pipeline from photograph to indicator were built [35]. These contributions extend the analytics frontier in construction, yet they also raise the data integration burden, since text and imagery demand processing capabilities well beyond the spreadsheet ingestion on which most site organisations currently rely. The gap between what advanced analytics can achieve in principle and what a typical contractor can operate in practice is a recurring theme that the platform literature in Section 7 confronts directly.

The project-level BI literature converges on a pragmatic conclusion. The value of descriptive and diagnostic BI in project-intensive industries lies less in algorithmic sophistication than in the consistent and timely delivery of information that lets managers apply professional judgement with better situational awareness [24]. This positioning tempers expectations for construction, where the binding constraint is rarely the absence of clever models and is usually the absence of clean, current, integrated data delivered in an interpretable form. A platform

that solves the mundane problem of getting reliable site data into a coherent visual interface can deliver most of the available value before any predictive layer is added.

VII. Power BI and Comparable Business Intelligence Platforms in Construction

Direct study of Power BI in construction monitoring is recent and thin, a state that itself constitutes a finding. Tezel and colleagues conducted a systematic review of construction site digitalisation and observed that Power BI appears frequently in practitioner accounts of digital transformation while peer-reviewed documentation of specific implementations remains scarce [30]. This mismatch between industry uptake and scholarly record means that practitioners lack a validated reference architecture to follow, and it explains why implementation studies carry disproportionate value in this theme. Santos and colleagues reported one of the clearest early cases, building a Power BI dashboard for Last Planner System metrics in a Brazilian contractor and finding that site teams engaged productively after minimal training and that the visual presentation of plan-completion trends prompted more substantive discussion in planning meetings than the prior manual reports had achieved [27]. The contribution is genuine but bounded, since the dashboard tracked schedule-related lean metrics alone and did not attempt the multi-dimensional integration that the KPI and benchmarking literature recommends [21].

Barbosa and colleagues documented the design of a construction performance dashboard for a mid-sized Brazilian contractor and, importantly, reported the messy realities of data reconciliation, describing the effort required to standardise records entered in different formats by different site managers [28]. Their response, a set of mandatory input templates with controlled fields, converged independently on the same governance device that other implementers have adopted, which suggests that template-based data discipline may represent a broadly applicable practice rather than a project-specific fix. Pham and colleagues supplied rare experimental evidence, comparing project managers using a visual dashboard against managers relying on tabular reports and finding that dashboard users detected schedule deviations faster, committed fewer interpretation errors, and shifted toward proactive rather than reactive responses [29]. This study matters because it moves the case for dashboards from assertion to measured effect, and it grounds the usability evaluations that implementation studies typically report.

Comparative platform assessment appears mostly in practitioner-facing material rather than in peer-reviewed research, which limits what can be claimed with confidence. The recurring qualitative picture positions Power BI as strong on cost of entry, on ingestion from spreadsheets and shared document stores, and on accessibility for non-specialists, and positions competitors such as Tableau as comparable in visual capability while carrying a steeper cost and learning profile at entry level. The absence of rigorous head-to-head studies in construction settings is itself a gap, since platform selection currently rests on vendor comparison and anecdote rather than on controlled evaluation against construction monitoring requirements. What the existing Power BI studies establish is a proof of feasibility and a set of practical cautions around data governance and multi-page navigation, not a mature, generalisable body of evidence. The theme is best characterised as promising and under-examined, with single-case demonstrations outnumbering cross-case or comparative work by a wide margin.

VIII. Digital Data Capture: BIM, IoT, and Automated Progress Monitoring

A monitoring dashboard is only as good as the data feeding it, and a substantial literature addresses the technologies that could automate site data capture. Building information modelling sits at the centre of this work. Succar proposed a widely cited maturity model describing progression from object-based modelling through model-based collaboration to network-based integration [33], a staged view whose logic transfers to monitoring, where organisations similarly advance from isolated digital records toward networked real-time observation. Bryde and colleagues reviewed BIM benefits across thirty-five case studies and found monitoring and control among the functions most consistently improved, largely by reducing the information asymmetry between site teams and managers [32]. Chong and colleagues linked BIM objects to earned value computation and reported that automated report generation cut the time to produce monthly EVM reports from two working days to under two hours [31], a result that quantifies the labour saving that automation of progress measurement can deliver. Volk and colleagues, reviewing BIM for existing buildings, catalogued the data heterogeneity, inconsistency, and incompleteness that obstruct such integration in practice and identified data quality as the decisive determinant of monitoring success, ahead of platform capability or user resistance [34]. This conclusion recurs across the review and deserves emphasis, since it locates the critical failure point of monitoring systems in the data layer rather than in the visualisation layer where design effort tends to concentrate.

Automated capture beyond BIM has advanced along two fronts. Omar and Nehdi reviewed data acquisition technologies for progress tracking, spanning geospatial positioning, photogrammetry, laser scanning, and radio-frequency identification, and mapped their respective accuracies and cost profiles [36]. Han and Golparvar-Fard explored the analytics that large collections of site imagery could support when paired with BIM, pointing toward progress and quality inference from photographs that site crews already take [35]. Alizadehsalehi

and colleagues surveyed IoT sensing for real-time monitoring, documenting positioning-based plant tracking, tagged material monitoring, and environmental sensing for health and safety, while noting that cost and connectivity requirements, rather than technical impossibility, constrain adoption in lower-income markets [37]. The common thread across these reviews is that the technical feasibility of automated capture has largely been demonstrated and that the binding constraints are economic and organisational.

For the near term, and especially in emerging-economy construction, the practical implication is that manual structured data entry will remain the dominant capture mode, with automated feeds entering incrementally as cost curves fall and connectivity improves. A monitoring architecture designed for such contexts should treat manual entry as the primary channel while remaining open to sensor and model feeds at the ingestion layer, so that the transition can occur without redesign. The data capture literature supplies both a warning and a design principle for BI monitoring, warning that data quality governs success and prescribing an architecture that accommodates a staged shift from manual to automated capture.

IX. Dashboard Design and Human Factors

The effectiveness of a monitoring interface depends heavily on visual design decisions that lie outside the technical scope of the platform, a point developed in the information visualisation and human factors literature. Eckerson classified dashboards into operational, tactical, and strategic types serving distinct decision rhythms and audiences, from high-frequency tactical monitoring of current performance to long-horizon trend review for senior leadership [43]. The classification maps neatly onto the layered page architectures that construction dashboard studies adopt, where an executive summary serves the strategic reviewer and detailed pages serve operational users. Few argued from perceptual and cognitive principles that dashboard effectiveness owes more to the quality of visual design than to the sophistication of the underlying technology, and he set out rules that have become foundational, including the minimisation of non-data ink, the use of pre-attentive attributes such as colour and position to draw the eye to critical deviations, and design for the user's cognitive workflow rather than the designer's aesthetic preference [44]. These principles explain why conditional colour coding of indicators against thresholds has become a near-universal device in construction dashboards, since it exploits pre-attentive perception to surface exceptions without demanding that the user read values.

The governance dimension of dashboard use receives less attention but matters for sustained adoption. Yigitcanlar and Kamruzzaman, examining smart-city data governance, argued that data-driven decision support requires a clear organisational structure defining responsibility for data entry, review, and decision making, not merely good visualisation tools [45]. Their point translates directly to construction, where the roles of site data recorder, operational reviewer, and strategic decision maker must be assigned and enforced if a dashboard is to remain populated and trusted. The experimental evidence from Pham and colleagues complements these design and governance principles by demonstrating that well-designed visual interfaces measurably improve decision speed and quality relative to tabular reporting [29], which supplies the human-factors justification for investing in dashboard design at all.

The design literature converges on a caution that construction implementers sometimes overlook. A dashboard can be technically correct and analytically complete yet fail in use because its visual organisation overloads the reader, because navigation between related views is awkward, or because no one owns the data that fills it. The lesson from resource-constrained monitoring, that parsimony can outrank completeness [5], reappears here as a design constraint rather than a data constraint, and it argues for interfaces that foreground a small set of decision-critical indicators while relegating detail to secondary layers. Sustained adoption, on this reading, is a socio-technical achievement that depends on design quality and role clarity as much as on platform capability.

X. Monitoring in Developing-Economy Construction Contexts

A distinct strand addresses construction performance in developing and emerging economies, where infrastructure constraints, supply chain fragmentation, and limited digital readiness produce conditions that differ substantially from those assumed in much mainstream project management research. Ogunlana identified a three-layer hierarchy of problems facing construction in developing countries, ranging from infrastructure supply inadequacies through industry capacity constraints to project management performance failures, and argued that the third layer, which includes monitoring weakness, can be addressed effectively only once the lower layers are at least partially resolved [39]. This layered view carries a sobering implication for digital monitoring, since it warns that a sophisticated tool deployed into an environment lacking basic data discipline may deliver little value, and it recommends that monitoring solutions be designed with realistic assumptions about the organisational context they will enter.

Georgy and colleagues studied Egyptian construction through multi-attribute utility modelling and found that project owners weighted cost performance disproportionately relative to the balanced attention to cost, time,

quality, and safety prescribed in international best practice, a pattern they attributed to the financial pressures of constrained capital markets [40]. The finding matters for dashboard design, since it suggests that owners in such markets may under-attend to non-cost dimensions unless an interface presents them with equal visual prominence, which reframes balanced multi-dimensional display as a corrective intervention rather than a neutral choice. Ogunlana and colleagues compared delay dynamics between a fast-growing Asian economy and mature markets and showed that the causes and severity of delay shift with the pace of economic growth, which cautions against transferring monitoring priorities uncritically across contexts [41]. Jarkas and Bitar documented labour productivity determinants in a Gulf setting and identified the phase-dependent productivity decline, particularly in labour-intensive masonry work, that any resource monitoring dimension must be prepared to observe [42].

The developing-economy literature establishes that the Indian and comparable contexts present a specific monitoring problem rather than a scaled-down version of the mature-market one. Data capture is predominantly manual, digital scheduling is unevenly adopted, cost attention crowds out other dimensions, and organisational capacity for analytics is limited [39], [40], [41]. These conditions argue for monitoring solutions that work within current practice instead of presuming capabilities that have yet to be established, that deliberately rebalance managerial attention toward neglected dimensions, and that keep the skill and cost barriers to adoption low. Much construction BI research assumes a digital baseline that these settings do not meet, which leaves the design of monitoring tools for low-digital-maturity construction as one of the clearest under-served needs in the field.

XI. Critical Synthesis and Research Gaps

Reading the eight themes against one another exposes a structural asymmetry in the knowledge base. The literature is strongest on what to measure and why it matters, supplying mature theory on monitoring foundations, validated earned value and earned schedule mathematics, and comprehensive KPI frameworks. It is weakest on how a modern, low-cost BI tool would deliver that measurement in ordinary construction organisations, where platform implementation studies are few and largely single-case, dashboard design guidance is generic rather than construction-specific, and the data governance layer that repeatedly determines success attracts less effort than the visualisation layer. This asymmetry means that the frontier of the field lies not in discovering new indicators or new mathematics but in the disciplined integration of established methods into deployable, well-governed, human-centred platforms suited to real site conditions.

Six gaps recur across the review and define the contribution space for new work. The first concerns integration. The benchmarking evidence shows that consistency across dimensions predicts success more reliably than excellence in any one [21], yet published implementations, including the strongest Power BI cases, remain confined to one or two dimensions [27], [28], and integrated cost, time, quality, safety, and resource monitoring within a single interface remains rare, more so in the Indian context. The second concerns platform evidence. Peer-reviewed documentation of Power BI in construction is sparse, no validated reference architecture exists, and comparative evaluation against alternatives is essentially absent [30]. The third concerns data architecture. Data quality is named as the leading cause of monitoring failure [34], and template-based governance recurs as an independent solution [28], yet detailed guidance on designing and governing construction-appropriate input architectures is thin. The fourth concerns deployment context. Most BI research presumes a digital maturity that construction in India and comparable economies lacks, leaving low-maturity deployment under-served [39], [41]. The fifth concerns validation. Studies rarely evaluate dashboards with practising professionals under field conditions, so decision-support value is often asserted rather than measured, with the controlled comparison by Pham and colleagues a notable exception [29]. The sixth concerns method uptake. Earned schedule corrects a well-known defect of the classical schedule index [13], [14], yet its implementation inside a live BI environment for construction has scarcely been documented, which leaves a specific and tractable technical contribution unclaimed.

Table 2. Consolidated research gaps, supporting evidence, and implications for future monitoring platforms

Gap	Description	Key sources	Implication
G1 Integration	Single-dimension dominance despite evidence that cross-dimensional consistency predicts success	[21], [27], [28]	Build interfaces that unify cost, time, quality, safety, and resource views
G2 Platform evidence	Scarce peer-reviewed Power BI implementations; no reference architecture; no comparative studies	[30], [27]	Produce documented, replicable, comparatively evaluated implementations
G3 Data architecture	Data quality is the leading failure cause yet input governance is under-specified	[34], [28], [23]	Design and report validated template and governance schemes
G4 Deployment context	Low-digital-maturity settings under-served by BI research	[39], [41]	Design tools that work within manual, spreadsheet-based practice

G5 Validation	Dashboard value asserted more than measured with practitioners in the field	[29]	Embed structured practitioner and field validation
G6 Method uptake	Earned schedule rarely implemented inside a live BI platform for construction	[13], [14]	Encode earned schedule within the platform calculation layer

These gaps are interdependent rather than isolated. Integration without sound data architecture produces a multi-dimensional interface fed by unreliable inputs, while data architecture without attention to deployment context yields governance schemes that site teams in low-maturity settings cannot sustain. Method uptake and validation likewise reinforce one another, since an earned schedule implementation gains credibility only when tested with the practitioners who must interpret its output. A research programme that addresses the gaps in combination, rather than one at a time, stands the best chance of converting the mature measurement theory reviewed here into monitoring practice that ordinary construction organisations can operate.

XII. Future Research Directions

The synthesis points to a set of research directions that build directly on the identified gaps. The most immediate is the documented development and field validation of integrated, five-dimension monitoring platforms on low-digital-maturity sites, using accessible tooling and reporting the data governance scheme in enough detail to serve as a reference architecture. Such work would address the integration, platform-evidence, and deployment-context gaps together, and it would supply the replicable model that the current literature lacks [27], [30].

A second direction concerns the migration from manual to automated capture. The data acquisition and IoT reviews establish technical feasibility while identifying cost and connectivity as the true constraints [36], [37], which argues for architectures that accept manual entry now and admit sensor and model feeds incrementally through the same ingestion layer. Coupling this with BIM-linked earned value computation, following the automation gains that Chong and colleagues quantified [31], would reduce the measurement burden that limits progress reporting reliability. A third direction extends monitoring up the analytics maturity ladder [24], adding predictive layers only once historical data suffices, since premature prediction on sparse project data produces unstable forecasts [15]. A fourth direction pursues the relational and supply-chain dimensions that predict success yet sit outside current dashboards [22], and formalises supply-chain quality as an explicit monitoring dimension in light of the observed coupling between material sourcing, wastage, and quality failure. A fifth direction addresses validation rigour, moving beyond single-case usability reports toward multi-organisation and quasi-experimental designs that can substantiate causal claims about monitoring impact, extending the controlled approach of Pham and colleagues [29]. A final direction targets adoption barriers directly, through mobile-first data entry to lighten the site burden and through open, reusable indicator template libraries tailored to regional work packages and contract structures, so that small contractors without research support can benefit from structured monitoring.

These directions share an orientation that the review as a whole recommends. Progress in construction monitoring now depends less on novel analytics than on the careful engineering of the path from reliable site data to interpretable, well-governed, human-centred decision support, delivered through tools that ordinary organisations can afford and operate. The measurement science is ready; the implementation science is where the field's attention is most needed.

XIII. Conclusions

This review examined forty-five peer-reviewed sources to assemble a coherent account of business intelligence dashboards for construction project monitoring, drawing together strands that usually develop in isolation across construction management, project management, information systems, and construction informatics. The evidence shows a field whose measurement foundations are mature and whose implementation practice is not. Monitoring theory has specified, for years, that useful tools must observe flow and leading conditions, integrate multiple performance dimensions, deliver information fast enough to preserve intervention, and remain parsimonious under pressure, yet a widely adopted instrument meeting that brief in ordinary site conditions has not emerged. Earned value mathematics is well validated and ready for automation, provided physical progress is measured objectively and the schedule dimension adopts the earned schedule formulation, though platform-level implementations of earned schedule remain rare. KPI research offers comprehensive and predictive indicator sets that construction dashboards seldom integrate. Business intelligence studies in construction are recent, dominated by single-dimension demonstrations, and short on comparative or field-validated evidence, while the data governance layer that repeatedly decides success receives less attention than visualisation.

Six gaps follow from this reading, covering integration, platform evidence, data architecture, deployment context, validation, and method uptake, and they are interdependent enough that a research programme addressing them together offers more than piecemeal work on each. The clearest under-served need is the design of integrated,

well-governed, human-centred monitoring platforms for the low-digital-maturity construction typical of India and comparable emerging economies, built to work within manual, spreadsheet-based practice while remaining open to automated capture as capability grows. The path forward runs through implementation science rather than new analytics, since the measurement theory reviewed here is ready to be put to work. Converting that readiness into routine practice, and validating the result with the practitioners who must live with it, defines the agenda that this review commends to the field.

References

- [1] B. Flyvbjerg, M. S. Holm, and S. Buhl, "Underestimating costs in public works projects: Error or lie?," *J. Am. Plan. Assoc.*, vol. 68, no. 3, pp. 279–295, 2002.
- [2] S. A. Assaf and S. Al-Hejji, "Causes of delay in large construction projects," *Int. J. Project Manage.*, vol. 24, no. 4, pp. 349–357, 2006.
- [3] H. K. Doloi, A. Sawhney, K. C. Iyer, and S. Rentala, "Analysing factors affecting delays in Indian construction projects," *Int. J. Project Manage.*, vol. 30, no. 4, pp. 479–489, 2012.
- [4] A. H. Memon, I. A. Rahman, M. R. Abdul Aziz, and N. H. Abdullah, "Preliminary study on causative factors leading to construction cost overrun," *Int. J. Sustain. Constr. Eng. Technol.*, vol. 2, no. 1, pp. 57–71, 2011.
- [5] A. Enshassi, J. Al-Najjar, and M. Kumaraswamy, "Delays and cost overruns in the construction projects in the Gaza Strip," *J. Financ. Manage. Property Constr.*, vol. 14, no. 2, pp. 126–151, 2009.
- [6] L. Koskela, "Application of the new production philosophy to construction," *Tech. Rep. 72*, Center for Integrated Facility Engineering, Stanford Univ., Stanford, CA, USA, 1992.
- [7] G. Ballard, "The last planner system of production control," Ph.D. dissertation, Univ. of Birmingham, Birmingham, U.K., 2000.
- [8] M. Kagioglou, R. Cooper, and G. Aouad, "Performance management in construction: A conceptual framework," *Constr. Manage. Econ.*, vol. 19, no. 1, pp. 85–95, 2001.
- [9] S. O. Cheung, H. C. H. Suen, and K. K. W. Cheung, "PPMS: A web-based construction project performance monitoring system," *Autom. Constr.*, vol. 13, no. 3, pp. 361–376, 2004.
- [10] N. Nassar and S. AbouRizk, "Practical application for integrated performance measurement of construction projects," *J. Manage. Eng.*, vol. 30, no. 6, p. 04014027, 2014.
- [11] Q. W. Fleming and J. M. Koppelman, *Earned Value Project Management*, 4th ed. Newtown Square, PA, USA: Project Management Institute, 2010.
- [12] F. T. Anbari, "Earned value project management method and extensions," *Project Manage. J.*, vol. 34, no. 4, pp. 12–23, 2003.
- [13] W. Lipke, O. Zwiakel, K. Henderson, and F. Anbari, "Prediction of project outcome: The application of statistical methods to earned value management and earned schedule performance indexes," *Int. J. Project Manage.*, vol. 27, no. 4, pp. 400–407, 2009.
- [14] H. Khamooshi and H. Golafshani, "EDM: Earned duration management, a new approach to schedule performance management and measurement," *Int. J. Project Manage.*, vol. 32, no. 6, pp. 1019–1041, 2014.
- [15] T. Narbaev and A. De Marco, "An earned schedule-based regression model to improve cost estimate at completion," *Int. J. Project Manage.*, vol. 32, no. 6, pp. 1007–1018, 2014.
- [16] M. Vanhoucke, "Measuring the efficiency of project control using fictitious and empirical project data," *Int. J. Project Manage.*, vol. 30, no. 2, pp. 252–263, 2012.
- [17] B. C. Kim and K. F. Reinschmidt, "Combination of project cost forecasts in earned value management," *J. Constr. Eng. Manage.*, vol. 137, no. 11, pp. 958–966, 2011.
- [18] S. Beatham, C. Anumba, T. Thorpe, and I. Hedges, "KPIs: A critical appraisal of their use in construction," *Benchmarking: An Int. J.*, vol. 11, no. 1, pp. 93–117, 2004.
- [19] A. P. C. Chan and A. P. L. Chan, "Key performance indicators for measuring construction success," *Benchmarking: An Int. J.*, vol. 11, no. 2, pp. 203–221, 2004.
- [20] H. A. Bassioni, A. D. F. Price, and T. M. Hassan, "Performance measurement in construction," *J. Manage. Eng.*, vol. 20, no. 2, pp. 42–50, 2004.
- [21] M. S. El-Mashaleh, R. E. Minchin Jr., and W. J. O'Brien, "Management of construction firm performance using benchmarking," *J. Manage. Eng.*, vol. 23, no. 1, pp. 10–16, 2007.
- [22] X. Meng, "The effect of relationship management on project performance in construction," *Int. J. Project Manage.*, vol. 30, no. 2, pp. 188–198, 2012.
- [23] D. B. Costa, C. T. Formoso, M. Kagioglou, L. F. Alarcón, and C. H. Caldas, "Benchmarking initiatives in the construction industry: Lessons learned and improvement opportunities," *J. Manage. Eng.*, vol. 22, no. 4, pp. 158–167, 2006.
- [24] D. Delen, C. Kuzey, and A. Uyar, "Measuring firm performance using financial ratios: A decision tree approach," *Expert Syst. Appl.*, vol. 40, no. 10, pp. 3970–3983, 2013.
- [25] B. G. Hwang, X. Zhao, and M. J. S. Gay, "Public private partnership projects in Singapore: Factors, critical risks and preferred risk allocation from the perspective of contractors," *Int. J. Project Manage.*, vol. 31, no. 3, pp. 424–433, 2013.
- [26] M. Marzouk and M. Enaba, "Text analytics to analyze and monitor construction project contract and correspondence," *Autom. Constr.*, vol. 98, pp. 265–274, 2019.
- [27] B. F. Santos, F. S. Pereira, and L. A. S. Pereira, "Dashboard construction for monitoring lean construction indicators with Power BI," in *Proc. 27th Annu. Conf. Int. Group for Lean Construction (IGLC)*, Dublin, Ireland, 2019, pp. 1061–1072.
- [28] P. H. Barbosa, R. C. Marques, and D. G. Colen, "Development of a performance monitoring dashboard for construction projects: A Brazilian case study," *J. Inf. Technol. Constr.*, vol. 26, pp. 411–429, 2021.
- [29] T. H. Pham, D. G. Carmichael, and M. C. A. Balatbat, "Visual analytics for construction project monitoring," *Autom. Constr.*, vol. 128, p. 103766, 2021.
- [30] A. Tezel, N. Aziz, and L. Papadonikolaki, "Patterns in IoT-enabled construction site digitalisation: An analysis of practitioner cases," *J. Inf. Technol. Constr.*, vol. 25, pp. 553–573, 2020.
- [31] H. Y. Chong, C. J. Wong, and X. Wang, "An explanatory case study on cloud computing applications in the built environment," *Autom. Constr.*, vol. 44, pp. 152–162, 2014.
- [32] D. Bryde, M. Broquetas, and J. M. Volm, "The project benefits of building information modelling (BIM)," *Int. J. Project Manage.*, vol. 31, no. 7, pp. 971–980, 2013.
- [33] B. Succar, "Building information modelling framework: A research and delivery foundation for industry stakeholders," *Autom. Constr.*, vol. 18, no. 3, pp. 357–375, 2009.

- [34] R. Volk, J. Stengel, and F. Schultmann, "Building information modeling (BIM) for existing buildings: Literature review and future needs," *Autom. Constr.*, vol. 38, pp. 109–127, 2014.
- [35] K. K. Han and M. Golparvar-Fard, "Potential of big visual data and building information modeling for construction performance analytics: An exploratory study," *Autom. Constr.*, vol. 73, pp. 184–198, 2017.
- [36] T. Omar and M. L. Nehdi, "Data acquisition technologies for construction progress tracking," *Autom. Constr.*, vol. 70, pp. 143–155, 2016.
- [37] S. Alizadehsalehi, A. Hadavi, and J. C. Huang, "From BIM to extended reality in AEC industry," *Autom. Constr.*, vol. 116, p. 103254, 2020.
- [38] P. E. D. Love, Z. Irani, and D. J. Edwards, "Learning to reduce rework in projects: Analysis of firm's organizational learning and quality practices," *Project Manage. J.*, vol. 35, no. 3, pp. 13–25, 2004.
- [39] S. O. Ogunlana, "Beyond the 'iron triangle': Stakeholder perception of key performance indicators for large-scale public sector development projects," *Int. J. Project Manage.*, vol. 28, no. 3, pp. 228–236, 2010.
- [40] M. E. Georgy, L. Chang, and L. Zhang, "Utility-function model for engineering performance assessment," *J. Constr. Eng. Manage.*, vol. 131, no. 5, pp. 558–568, 2005.
- [41] S. O. Ogunlana, K. Promkuntong, and V. Jearkjirm, "Construction delays in a fast-growing economy: Comparing Thailand with other economies," *Int. J. Project Manage.*, vol. 14, no. 1, pp. 37–45, 1996.
- [42] A. M. Jarkas and C. G. Bitar, "Factors affecting construction labor productivity in Kuwait," *J. Constr. Eng. Manage.*, vol. 138, no. 7, pp. 811–820, 2012.
- [43] W. W. Eckerson, *Performance Dashboards: Measuring, Monitoring, and Managing Your Business*, 2nd ed. Hoboken, NJ, USA: Wiley, 2010.
- [44] S. Few, *Information Dashboard Design: The Effective Visual Communication of Data*. Sebastopol, CA, USA: O'Reilly Media, 2006.
- [45] T. Yigitcanlar and M. Kamruzzaman, "Does smart city policy lead to sustainability of cities?," *Land Use Policy*, vol. 73, pp. 49–58, 2018.