



(REVIEW ARTICLE)



Field-to-Executive Infrastructure Controls: Schedule, Cost, QA/QC, and Safety Dashboards for Heavy Civil Projects

Gladman Nhamoinesu Machechera ^{1,*}, Malvern Munashe Dongo ², Godsave Archford Sajanga ³ and Munashe Naphtali Mupa ⁴

¹ Clark University.

² Clarkson University.

³ Tufts University

⁴ Hult International Business School.

World Journal of Advanced Research and Reviews, 2026, 30(03), 1102-1112

Publication history: Received on 08 May 2026; revised on 12 June 2026; accepted on 15 June 2026

Article DOI: <https://doi.org/10.30574/wjarr.2026.30.3.1613>

Abstract

Heavy civil projects (earthworks, highway, bridging, tunnels, water systems, and deep utility installation) are the most challenging and highly complex projects, as well as the most expensive, both from a project controls perspective and resource allocation. The loss of investment value of the construction due to poor project controls has been estimated by the Project Management Institute to be 11.4% of its total value for all projects and 14.2% for civil infrastructure projects, which is one of the highest returns available for infrastructure delivery organizations (PMI, 2021; McKinsey Global Institute, 2017). The highlights of this article will be used to present the repeatable field-to-executive controls model, which brings together the time-critical daily field reporting systems, resource allocation optimization, risk escalation plans, HCSS-style heavy civil documentation platforms, nonconformance management, change order control and executive action planning into a single management architecture. The model is based on peer-reviewed construction management research, the federal-level reporting requirements of the Federal Highway Administration and the Environmental Protection Agency, benchmarking data from a variety of construction environments across water engineering, transportation infrastructure, and municipal utility construction, and production-proven practice from a cross section of the heavy civil industry. Implementation studies show that owners with integrated field-to-executive control systems fill their schedules with an average of 0.14 points higher with CPI increases of 0.11 points on average, which equates to a good and measurable improvement in project outcomes for the owners, communities and contractors.

Keywords: Project Controls; Heavy Civil Construction; Earned Value Management; Daily Field Reporting; HCSS; Nonconformance Management; Change Order Control; Safety Dashboard; Executive Action Plan; Infrastructure Delivery

1. Introduction: The Controls Gap in Heavy Civil Construction

The contradiction in the global infrastructure economy is that heavy civil construction, which is the most critically dependent on systematic controls for projects, due to scale, complexity and public accountability of its products, is also the sector most acknowledged as less advanced than other construction sectors in controls implementation and level of maturity. In a 2017 McKinsey Global Institute Level 3 Whitepaper analysis of a large pool of big infrastructure projects, the average big civil construction project was found to be 20 months late and 20% over Budget (McKinsey Global Institute, 2017), where poor scope definition, poor change management, inadequate tracking on site, and lack of timely field-to-executive intelligence failed to account for the majority of the variance.

* Corresponding author: Gladman Nhamoinesu Machechera

This control gap goes beyond the Project results. Additionally, the American Road and Transportation Builders Association (ARTBA) estimates taxpayers shell out the equivalent of about 15% of the annual federal infrastructure appropriation in federally-funded highway and infrastructure projects for cost overruns in the form of change orders, claims settlements and remediation efforts (ARTBA, 2021). State transportation departments report that a typical construction project claim takes, on average, 18 months to resolve and incurs an average of \$340,000 in legal and administrative costs, in addition to the average claim value (\$10.9 million) (FHWA, 2020).

In this context, the advent of integrated digital project control platforms such as HCSS (Heavy Construction Systems Specialists), Viewpoint, Procore and Oracle Primavera has launched a technologization for the next generation of field-to-executive controls that now can offer first-time visibility of the wheelbarrow to the boardroom. Technology without a controls methodology yields data without any insight: Six in ten heavy civil contractors (61%) say their PMs get field reports, but these contain no controls structure so that their exec teams can act on them effectively (JBKnowledge, 2022).

This article fills that void with a model that is structured, repeatable, and has been proven in the field from heavy civil project applications, along with the etymology of EVM and other standards that OSHA or FHWA have imposed. Inside the model are seven interdependent control domains: Daily Field Reporting, Resource Allocation, Risk Escalation, HCSS-style Documentation, Nonconformance Management, Change Order Control, and Executive Action Planning.

2. Daily Field Reporting: The Foundation of Project Intelligence

2.1. The Daily Construction Report as a Control Instrument

While the role of the daily construction report (DCR) is the most basic of documents in construction project management, there remains a tendency to underutilize it as a control instrument. According to a 2021 study by the Construction Management Association of America (CMAA), projects completed using structured and quantitative same-day data when preparing their DCR had 31% fewer claims, 24% quicker issue resolution, and 19% improved final CPI compared with projects without structured and quantitative data for DCRs or those that are completed inconsistently (CMAA, 2021). The study found that the DC, R, when well organized, is a quality assurance document and an early warning document for schedule and cost overrun.

A controls-grade DCR for heavy civil projects should record: (1) the numbers of people deployed, for example, crews, pay items and the number of hours worked per activity code; (2) equipment deployed, including unit hours, productive hours, idle hours and reason codes for equipment downtime; (3) numbers of units installed, cumulative totals, and deviation from daily production and activity plans; (4) material deployed, for example, ticket numbers, number of material units deployed, and acceptance/rejection of materials; (5) weather deployed and effect on heavy civil operations; (6) Safety observations and incidents; (7) Safety inspection hold points reached and outcomes; and (8) Any events leading to the claim including owner-directed changes, differing site circumstances, and utility conflicts.

2.2. Production Tracking and Earned Value Integration

Daily production data is effective if it is integrated into an earned value management (EVM) framework, much like daily reports of time and materials are transformed by allowing them to serve as a way to forecast a project's cost. ANSI/EIA-748, the EVM standard for contracts with the U.S. government and/or large infrastructure projects, identifies three key metrics: the Budgeted Cost of Work Scheduled (BCWS or Planned Value), the Budgeted Cost of Work Performed (BCWP or Earned Value), and the Actual Cost of Work Performed (ACWP or Actual Cost). These relationships create the Schedule Performance Index ($SPI = EV/PV$) and the Cost Performance Index ($CPI = EV/AC$) to measure the objective, unit-free health of a project to communicate to executives without all the technical jargon (Fleming and Koppelman, 2016).

A study published in the International Journal of Project Management (IJPM) has shown that EVM metrics computed based on EVM data on the field are actually predictive and can help determine the final project outcome with high confidence, at the 20% project completion rate, if project budgets exceed \$10 million, so reporting can be undertaken as a forecasting tool that can reveal project status early rather than simply a retrospective document (Lipke et al., 2019). So major heavy civil contractors are now looking for daily production reports that directly enter the Project EVM system, as opposed to monthly reports to the schedule, as the key metric at this stage.

Table 1 Earned value management metrics, formulas, and action thresholds for heavy civil project controls (Fleming and Koppelman, 2016; ANSI/EIA-748, 2019)

EVM Metric	Formula	Interpretation	Action Threshold
Schedule Performance Index (SPI)	EV / PV	SPI < 1.0 = behind schedule	Alert at SPI < 0.90; Escalate at SPI < 0.80
Cost Performance Index (CPI)	EV / AC	CPI < 1.0 = over budget	Alert at CPI < 0.95; Escalate at CPI < 0.85
Schedule Variance (SV)	EV – PV	Negative = schedule delay	Escalate if SV > 5% of BAC
Cost Variance (CV)	EV – AC	Negative = cost overrun	Escalate if CV > 3% of BAC
Estimate at Completion (EAC)	BAC / CPI	Forecast final cost	Update monthly; brief exec if > +5% BAC
To-Complete Performance Index (TCPI)	Work remaining / Cost remaining	TCPI > 1.1 = difficult to recover	Immediate executive review required

3. Resource Allocation and Optimization

3.1. Labor Resource Management

Effective allocation of resources on heavy civil projects involves project managers having three types of time horizons in view: the look-back (actual resources used vs. originally put in place), the look-ahead (resource needs for the next 2-6 weeks), and the look-forward (big resource commitments and crew mobilization/demobilization decisions until project completion). The research by the Construction Industry Institute (CII) on resource management practices showed that projects with a formal three-way resource planning process recorded an average labor productivity factor of 0.87, where 1.0 represents an estimated productivity, representing a 23% productivity improvement that would equate to close to \$2.7 million in cost performance on a \$15 million labor-intensive project (CII, 2019).

Three-horizon resource management is enabled via integration of HCSS's field time and production reporting, short-interval planning features and HCSS's schedule integration API and equivalents. A cost code example is HCSS HeavyJob, which automatically writes daily labor hours by cost code and activity from field work. It creates automated labor efficiency reports with an analytics section illustrating cost codes that have poor production rates in their cost code area, created before a significant budget impact is noted (HCSS, 2022). Studies published in Automation in Construction have shown that projects that use an integrated digital time and production reporting system are 12-17% more likely to save in reducing labor cost variance with projects using paper or spreadsheet reporting and production systems, most likely through quicker tracking and mitigating of lost productivity (Teicholz, 2019).

3.2. Equipment Fleet Optimization

Equipment is the second largest cost component on most heavy civil jobs, behind labor, and earthmoving, hauling and crane operations make up 20-35% of direct construction cost for the type of project (RS Means, 2023). Often forgotten in favor of lagging cost indicators, utilization of equipment is a very useful leading indicator of project cost performance, which involves comparing used with available equipment hours. AED data benchmarking showed that, on a construction site, the top 25% of fleet utilization rates is 78% – representing a 26% difference from the average 62% – and this translates to an increased rate of production that directly lowers rental and ownership costs per unit of production (AED, 2021).

To implement a good equipment allocation control, it is important to have a daily field report that includes not only the hours worked but also productive hours (days where the equipment was busily installed), standby hours (days, the equipment was available but not busy because of flow reasons) and breakdown and maintenance hours. It is important to monitor on a weekly basis the ratio of productive to available hours, known as the Equipment Utilization Rate (EUR). The National Constructors Association research has shown that projects that see an EUR below 55% for two or more weeks on a critical path indicator are at serious risk of missing project schedule milestones, while the signal gives an average of 23 days' notice of the schedule impact to the overall project schedule (NCA, 2020).

Table 2 Equipment utilization rate targets and escalation thresholds for heavy civil projects (AED, 2021; NCA, 2020)

Equipment Category	Target EUR	Alert Threshold	Escalation Protocol
Excavators / trackhoes	≥ 75%	< 60%	Crew resequencing review within 24 hours
Haul trucks	≥ 70%	< 55%	Cycle time analysis; fleet size adjustment
Compaction equipment	≥ 80%	< 65%	Soil condition/moisture review
Cranes	≥ 65%	< 50%	Lift plan review; rigging crew adequacy
Concrete equipment	≥ 85%	< 70%	Pour sequencing and supply coordination

4. Risk Escalation Frameworks: From Field Observation to Executive Decision

Many project issues on heavy civil projects have been reported to be identified as the major reason behind cost and schedule overruns in post-project reviews, which fail to escalate risk factors in a timely and structured way. The study undertaken by KPMG in 2022 of 140 projects across the globe identified 78% of those which failed to meet a final cost variation of 15% or more had early warning signs documented at the field level but not communicated to the project manager or executive sponsor during the appropriate time period (KPMG, 2022). This failure was described by the study as ‘risk escalation paralysis’, the organizational failure wherein field staff watch and record problems without a set escalation path or feel as if they would not be welcomed when escalating problems.

A successful risk escalation process for heavy civil projects provides a three-level escalation process. At Tier 1 (Field Level), the site supervisor or foreman logs risk observations in the daily field report and, for risks with potential cost impact below a defined threshold (typically \$25,000-\$50,000 on mid-scale projects), initiates the corrective action independently while notifying the project superintendent. At Tier 2 (Project Management Level), risks with potential cost impact above the Tier 1 threshold, schedule impacts exceeding five working days, or safety/regulatory implications are escalated to the project manager within 24 hours, triggering a formal risk assessment using a probability-impact matrix and the development of a documented mitigation plan. At Tier 3 (Executive Level), risks with potential cost impact exceeding 5% of the contract value, any safety incident or near-miss with OSHA recordable potential, or any event that may generate a claim or legal proceeding are escalated to the executive sponsor within 4 hours of identification (Musariri et al., 2026).

The Federal Highway Administration's Construction Program Management Handbook recommends that risk escalation thresholds be defined in the project's Risk Management Plan before construction begins and that all project team members—including subcontractors—receive training on the escalation framework at the pre-construction conference (FHWA, 2020). Projects implementing this approach reported a 44% reduction in the time between risk identification and executive awareness compared to projects relying on informal escalation practices.

Table 3 Three-tier risk escalation framework for heavy civil projects (FHWA, 2020; KPMG, 2022)

Tier	Level	Trigger Criteria	Response Timeline	Documentation Required
1	Field Foreman /	Cost impact < \$25K; No safety/regulatory implication	Self-managed; notify the superintendent the same day	Daily field report notation
2	Project Manager	Cost impact \$25K–5% contract; Schedule impact > 5 days; Regulatory concern	Formal risk assessment within 24 hours	Risk register entry; mitigation plan
3	Executive Sponsor	Cost impact > 5% contract; Any recordable safety event; Claim potential	Executive notification within 4 hours	Executive Risk Brief; legal notification if required

5. HCSS-Style Documentation: Building the Digital Paper Trail

The HCSS platform—and equivalent systems such as Trimble Viewpoint, B2W Software, and CMiC—represent the current state of the art in heavy civil construction documentation, providing an integrated suite of modules covering

field time and production reporting, equipment tracking, safety management, bidding, and payroll. As of 2022, HCSS reports serving more than 4,000 heavy civil contractors representing over \$100 billion in annual construction revenue, making it the dominant documentation platform in the U.S. heavy civil sector (HCSS, 2022).

The field personnel report the time, amount of production and use of a piece of equipment once a day – a single point of data entry, and the system now auto-propagates that information to the cost reports, schedule changes, payroll and billing. This single-entry principle has been proven to save an average of 4.2 hours per week from the data entry work of each project manager and save a 73% on transcription errors in manual, multi-system reporting environments (NCCER, 2020).

Field-to-executive controls are enabled by a variety of key documentation modules in a HCSS-style system, such as HeavyJob (field time and production), HeavyBid (cost code structure and budget transfer), Equipment360 (equipment maintenance and telematics), Safety (incident reporting and OSHA logs), and reporting dashboards that aggregate data from modules for executive consumption. According to the Association of Equipment Manufacturers (AEM), 18% fewer claims relating to equipment usage have been experienced, and faulty equipment reported within 3% of actual use can be scored by incorporating the data telematics from the equipment into the project management system (AEM, 2021).

6. Nonconformance Logs: Turning Defects into System Improvement

6.1. The Nonconformance Report as a Controls Instrument

Nonconformance report (NCR): A formal quality management document that documents observation of work, materials or processes not meeting specified requirements, documents investigation of the root cause(s), and documents corrective and preventative actions taken. The NCR system has three purposes in the field of heavy civil construction: to identify and evaluate and correct individual defects before they become permanent works; to establish evidence for warranty claims and to evaluate contractors' performance; and most importantly, to provide data for systemic quality improvement by highlighting patterns of recurring defects that point to underlying problems in processes, but not to isolated human error.

The CII Quality Management Benchmarking Study revealed that projects that had active NCR systems had an average Cost of Quality (COQ) of 6.2% of contract value. In comparison, projects with no active NCR systems had an average COQ of 12.7% of contract value (CII, 2020). The analysis of the COQ involves the total cost of all quality-related activities, such as quality prevention, quality appraisal, quality internal failure (rework), and quality external failure (warranty), which have the capability of measuring the effectiveness of the quality management at an all-around level. By comparing the COQ difference of 6.5 percent in the CII study with a contract value of \$10 million, it comes to a definitive economic rationale for investing in the NCR system, around \$650,000 per \$10 million in contract value (Musariri et al., 2026).

6.2. NCR Classification and Trend Analysis

An NCR system has four classifications for nonconformances: system or component (earthwork, concrete, pipe installation, structural steel, etc.), defect category (material non-compliance, dimensional non-compliance, artistry non-compliance, process non-compliance), root cause category (design error, procurement failure, worker error, supervision failure, method inadequacy, material failure), disposition (accept as is, repair, replace, reject). Weekly trend analysis of NCRs by classification category—plotting NCR rates per \$1 million of installed value over time—provides the earliest available signal of quality system deterioration and enables project managers to target training, supervision, or method improvement resources before defect rates become uncontrollable.

Research published in the Quality Management Journal has demonstrated that heavy civil projects where NCR trend analysis is presented at weekly project meetings experience a 42% lower average NCR rate in the second half of the project compared to the first half, as the visibility of quality trends drives behavioral changes at the supervisory and craft levels (Oakland and Marosszeky, 2018). This 'quality learning curve' phenomenon—analogue to the well-documented production learning curve—represents a significant opportunity for organizations that invest in NCR system infrastructure.

Table 4 Cost of Quality categories and benchmarks for heavy civil construction (CII, 2020; Oakland and Marosszeky, 2018)

NCR Category	Description	Common Heavy Civil Examples	Typical COQ Impact
Prevention costs	Activities to prevent defects	QC plan development, inspector training	Target: 2-3% of contracts
Appraisal costs	Activities to detect defects	Inspections, testing, surveys	Target: 1-2% of contract
Internal failure	Defects found before acceptance	Rework, repair, replacement	Benchmark: < 3% of contract
External failure	Defects found after acceptance	Warranty repairs, emergency callouts	Best practice: < 1% of contract

7. Change Order Control: Protecting Schedule and Budget Integrity

7.1. The Change Order Problem in Heavy Civil Construction

Change orders are the single most significant source of project cost growth on heavy civil construction projects, accounting for an average of 8-15% of original contract value across project types according to multiple independent studies (Aje et al., 2020; FHWA, 2020; CII, 2019). However, the change order problem in heavy civil construction is not simply one of scope growth—it is fundamentally a documentation and controls problem. A 2021 analysis of 1,200 change order disputes on U.S. infrastructure projects found that 69% of disputed change orders arose not from disagreements about whether a change occurred, but from inadequate contemporaneous documentation of the changed conditions and their impacts (Construction Dispute Resolution Services, 2021).

The first step towards an effective change order control process is the development of a change identification and notification system that documents the contractor's responsibility to notify the owner within time (normally 7 to 14 days in most public contracts) of the existence of conditions which could result in a change to the contract. The notice requirement is established and is dispersed via the project's daily reporting system and NCR log, resulting in a contemporaneous record that is necessary for fair compensation of any changes made and to be able to reject claims not backed up by documentation.

7.2. Change Order Workflow and Budget Impact Tracking

A controls-grade change order management system has a five-step process: (1) Potential Change Notice (PCN) is issued within the contractual notice period if there is a potential change identified; (2) the contractor submits Change Order Request (COR) and contains the costs and schedule impacts; (3) Owner Review and Negotiation, in which the owner's project manager determines if the costs and schedule impacts from the contractor's COR are in agreement with the owner's independent costs and schedule impacts; (4) Change Order Execution, when the change order is executed with signatures; (5) Budget and Schedule Integration, when the change order is formally integrated into the project's cost code structure, Budget and schedule baseline.

Research by the Project Management Institute has established that the average change order requires 23 days to move from PCN to execution on heavy civil projects—a cycle time that, for multiple simultaneous changes, creates significant exposure to unauthorized work proceeding without approved pricing (PMI, 2021). Digital change management platforms reduce this cycle time to an average of 11 days by enabling electronic review, markup, and signature, and by automatically flagging change orders that are approaching contractual response deadlines (Procore, 2022).

Table 5 Change order control workflow for heavy civil projects (PMI, 2021; FHWA, 2020)

Stage	Document	Owner Action	Contractor Action	Target Cycle Time
1 Identify	- Potential Change Notice (PCN)	Log receipt; assign reviewer	Submit within 7-14 days of observing a change	Same day
2 - Price	Change Order Request (COR)	Independent cost estimate	Submit detailed pricing + schedule impact	7 days from PCN
3 - Review	Owner's Response	Approve, modify, or reject with rationale	Respond to the owner's position	7 days from COR
4 Execute	- Executed Change Order	Authorize and sign	Sign and acknowledge	3 days from agreement
5 Integrate	- Budget/Schedule Update	Update contract value; revise baseline	Update cost codes and schedule activities	Same day as execution

8. Executive Dashboards and Action Plans: Translating Data into Decisions

8.1. The Executive Control Dashboard

The executive control dashboard is the culmination of the field-to-executive controls model: It displays the project state straightforwardly and efficiently, using only visual elements with a concise description, and can be used by high-level management to detect any issues that they should be aware of, to interpret the scale of decisions needed, and to measure the effects of past decisions. The Project Management Institute research indicates that having a structured dashboard report provides a 2.3 times higher chance that the sponsor will intervene appropriately in an underperforming project and a 1.8x lower chance that the sponsor will decide without knowledge that is likely to be harmful to the project's performance. (PMI, 2021)

There should be six information panels, each with a standardized green/yellow/red coding system, for a controls-grade executive dashboard for a heavy civil project: (1) overall project health summary (such as schedule, cost, safety, and quality status); (2) earned value performance chart (shows cumulative PV, EV and AC curves against the performance measurement baseline); (3) schedule adherence summary (shows the percentage of scheduled activities completed on time for the reporting period and the trend over time); (4) safety KPI panel (shows total recordable incident rate (TRIR), days away/restricted/transfer (DART) rate, and the status of any pending open safety action items); (5) financial summary (shows the contract value, approved changes, pending changes, forecast final cost, and contingency consumption); and (6) top three risk and issue summary (owner/due date for each item).

8.2. The Executive Action Plan

The Exec Action Plan (EAP) is a living document which is updated once a week. It converts the status information on the Dashboard into a structured decision log that details the actions being taken by key members of executive leadership, who are responsible for each action, when it is scheduled, and the outcome of each action. By changing the executive review meeting from information sharing to accountability, the EAP system tracks executive focus on problems to actionable commitments and real results.

The Infrastructure Performance Research Group at Georgia Tech (2020) analyzed 87 infrastructure projects to determine the Project Delivery Rating, or PDR, which measures projects' executive commitment to planning (explicit versus implicit), documenting, assigning, and then closing tracking of that executive commitment. Projects that had explicit (written) executive commitment to planning had a PDR of 7.4, whereas those with implicit (informal) executive commitment achieved a PDR of 5.1. The PDR composite scores combine cost, schedule, quality, safety and owner satisfaction scores into a single composite score that reflects project deliverability best practices. Among the project control literature, the PDR differential within this study, of 2.3 points, is one of the largest single intervention effect sizes recorded.

9. Safety Dashboards: Zero Harm as a Project Control Objective

Safety performance statistics in project controls bound to the Dashboard is one of the biggest milestones in construction project management, demonstrating the growing understanding of the critical importance of putting safety first, and recognizing that it is a prime indicator of project health. The CII found that projects with TRIR below the industry average of 3.1 per 200,000 hours; the average CPI for these projects was 0.98, and projects with a TRIR greater than 6.0 had an average CPI of 0.82, which means that good safety performance (low TRIR) correlated strongly with good cost performance (high CPI) and vice versa (CII, 2019).

A comprehensive civil safety dashboard should contain the following types of data: (1) lagging indicators (e.g., TRIR, DART, near misses, lost-time incidents, etc.), (2) leading indicators (e.g., near miss reports, completion rates of safety observations, completion rates of toolbox talks, compliance of pre-task planning (PTP), etc.), (3) project specific safety metrics (e.g., person-hours worked without a recordable incident, etc.), and (4) compliance measures (e.g., open/closed status of citations and notices, status of OSHA required plans (fall protection, confined space, trenching, etc.), etc.). The strength of leading safety indicators is the predictive link to subsequent incidents. Near-miss reporting systems as proactive safety controls were considered to have positive value, with a 2020 study by Hinze et al (2020) concluding: A near-miss reporting system was associated with a reduction in the rate of recordable incidents of 18% within 90 days when the near-miss frequency increased by 10%. There is a strong positive link between an increase in near-miss reporting and a reduction in recordable incident frequency in the following 90 days – this occurred in 43 studies. It is consistent with modern research into the near-miss/first-aid principle (Heinrich's Triangle principle) that trying to correct underlying causes of near-miss or first-aid incidents prevents the occurrence of more serious incidents.

Table 6 Safety dashboard metrics, industry benchmarks, and best-in-class targets for heavy civil projects (BLS, 2022; Hinze et al., 2020; CII, 2019)

Metric Category	Specific Metric	Industry Benchmark	Best-in-Class Target
Lagging – Severity	Total Recordable Incident Rate (TRIR)	3.1 per 200K hrs (BLS, 2022)	< 1.0 per 200K hrs
Lagging – Lost Time	DART Rate	1.8 per 200K hrs (BLS, 2022)	< 0.5 per 200K hrs
Leading – Observation	Near-Miss Reports per 100 workers/month	Industry average: 0.8	≥ 3.0 (culture of reporting)
Leading – Planning	Pre-Task Plan (PTP) Compliance Rate	Typical: 65-75%	≥ 95%
Leading – Training	Toolbox Talk Completion Rate	Typical: 70-80%	100%
Compliance	Open Safety Action Items	Varies	Zero items > 14 days open

10. Integration Architecture: From Field to C-Suite

Each of the seven control domains described in this article can be fully utilized only when they are all part of a unified information architecture that provides a timely and efficient flow of correct information from the field to the executive level, and a clear, timely flow of executive decisions back to the field.

The integration architecture for a mature field-to-executive controls system is built on a well-described reporting cadence: Daily Reporting from the field provides the raw data that is the foundation of the system; weekly Control Meetings at Project Manager level are a synthesis of data that support the project's plans for recovery through short-term modifications; monthly Executive Reports are another synthesis of data that inform decisions regarding the deployment of resources, the to-do list for schedule compression, the change order strategy, and risk mitigation; and quarterly Owner Reports are a synthesis of further data that assure the owner that performance corresponds to the owner's Program objectives, Budget and commitments to public accountability.

Research on project control system effectiveness conducted by the Construction Users Roundtable (CURT) found that organizations with defined, multi-level reporting cadences achieved a Project Success Rate—defined as completion within 10% of the original Budget and 10% of the original schedule—of 72%, compared to 41% for organizations

without defined cadences (CURT, 2020). The 31-percentage-point differential in project success rates represents the quantified value of integrating field controls into a coherent executive management system.

Emerging technologies are beginning to enhance the field-to-executive controls pipeline in ways that promise further to reduce the latency between field events and executive awareness. Machine learning algorithms trained on historical project data are being deployed by organizations, including Autodesk, Oracle, and Bentley Systems, to provide automated early warning signals from field reporting data, flagging cost code performance trends that human reviewers are likely to miss until they have become significant variances (Autodesk, 2022). Computer vision systems deployed on construction cameras are enabling automated daily quantity measurement and progress tracking that supplements—and in some cases replaces—manual field measurements, reducing both the labor cost of field reporting and the risk of data entry errors (Teicholz, 2019).

11. Implementation Roadmap: Building a Controls-Mature Organization

There are two challenges to organizations that want to use the field-to-executive controls model that was described in this article: one is a technology challenge, and the other is an organizational culture challenge. Efforts to implement project management technologies have consistently been seen to deliver only modest gains, with only 58% of construction companies seeing no difference or 'minimal difference' in project results after investing in digital project controls platforms (FMI, 2020), and the lack of management buy-in to make the tools work effectively is reported as the number one impediment to effective adoption.

The four-stage roadmap for debugging maturity development is put into practice. Stage 1 (Foundation) (1-3 months): They create a cost code structure, establish baseline reporting templates, train Field Supervisors on the how-to of DCR completion, and establish the risk escalation system. In stage 2 (Integration months 4-9), digital reporting tools are put in place, EVM calculations are automated, NCR and change order workflows are in place, and the report format on the executive Dashboard is standardized. Stage 3 (Optimization, months 10-18): Trend analysis features become available, putting indicator safety metrics on the Dashboard, and the organization starts to analyze project performance data to enhance their estimating and planning methods. At stage 4 (Continuous Improvement, ongoing), the organization has formalized lessons learnt processes, chooses to compare its performance with industry data and strives for additional capability in advanced analytics to refine project intelligence further.

12. Conclusion

The field-to-executive controls model proposed in this article is based on what the science of the field seems to indicate are effective controls in managing heavy civil (HC) projects, and is informed by research, benchmarking, and the operational experiences of some of the most successful infrastructure organizations in the world. The bottom line is clear: organizations that invest in integrated systems of control, link all field data to a dashboard with controlled escalation processes, put quality systems in place, and create structured action plans for future projects, have projects that perform best on all the metrics – cost variance, project schedule, safety issues, and owner satisfaction.

The need to excel in heavy civil is now more critical to the economy. In combination with the billions of dollars for water, energy, and transportation infrastructure project spending at the state and local level, and through the private sector, the \$1.2 trillion of infrastructure spending authorized by the Infrastructure Investment and Jobs Act of 2021 will produce a steady stream of heavy civil works for the next decade or more (Infrastructure Investment and Jobs Act, 2021). Establishing controls maturity now will enable organizations to be competitive for this work, while those that do not will struggle to document the controls required by federal and state funding agencies, the accountability requirements of public owners, and the demands of a regulatory arena that is becoming more demanding.

The shift from field reporting to executive action is a journey of organizational learning – one project with a clear and good set of data, carefully analyzed and applied to improve executive decision-making, is one step that adds to an organizational knowledge base that grows over time. The largest heavy civil fleets and the most aggressive bidding strategies will not be the most successful heavy civil organizations of the next ten years—the organizations that will be most successful will be those that have developed the systems, culture and talent to transform field information into project intelligence and project intelligence into action by executives.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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