SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 8822-8835
Open Access. Online & Print

DOI: 10.5281/zenodo.20096195

# INTEGRATED PROJECT MANAGEMENT APPROACHES FOR SUSTAINABLE ARCHITECTURAL AND CIVIL ENGINEERING INFRASTRUCTURE DEVELOPMENT

**[1*]Vikas Prakash Jadhao, [2]Dr M. Sandra Carmel Sophia, [3]M. Mariappan, [4]AUGUSTO ELIAS GARCIA CORZO, [5]Dr. Anduri Sreenivasulu, [6]Pradyut Chowdhury.**

*[1*]Assistant professor (Civil Engineering), Government College of Engineering, Jalgaon (Maharashtra) NH-6, Jalgaon- 425001 (Maharashtra, India), Email Id: jadhaovikas@gmail.com*
*[2]Professor, Department of English, Specialization in English Literature, Koneru Lakshmaiah Education Foundation Deemed to be University, Guntur Disrict-522302, Andhra Pradesh, Orcid Id: https://orcid.org/0000-0001-6857-2361, Email Id: sophia@kluniversity.in*
*[3]Associate Professor, Department of Civil Engineering, Dr. Mahalingam College of Engineering and Technology, Pollachi, Tamil Nadu, India, Email Id: mariappan.m2009@gmail.com*
*[4]NATIONAL UNIVERSITY OF CENTRAL PERU, Email Id: aegarcia@uncp.edu.pe*
*[5]Professor, Department of Civil Engineering, Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru - 521356, Krishna District, AP, India, Orcid Id: https://orcid.org/0000-0001-8436-1548, Email Id: asreenivasulu@gmail.com*
*[6]Assistant Professor, Department of Mechanical Engineering, 398, Ramkrishnapur Rd, near Jagadighata Market, Barasat, Kolkata, West Bengal 700125, India, Orcid Id: 0009-0009-2178-6739, Email Id: pradyutchowdhury14@gmail.com*

Received: 25/08/2025
Accepted: 22/01/2026

*Corresponding Author: Vikas Prakash Jadhao (jadhaovikas@gmail.com)*

## ABSTRACT

***Integrated project management is very important in the development of sustainability-oriented results in architectural and civil engineering infrastructure development especially where the quality of governance and reliability of execution are the factors that define the value in the long-term. Multi-project management data based on task-level execution were converted to project-level performance measures to test the financial deviation trends, the task completion patterns, coordination stability, and human resource execution dynamics in different project environments. The operationalization of sustainability focused on managerial and operational proxies, where reliability of execution and financial discipline were of greater importance than the environmental indicators. The analysis shows that there is high prevalence of negative cost variance and high execution progress which implies systematic decoupling of financial reporting and task progress. Status classifications of the declared project status have poor correlation with the achieved completion levels, which underscores governance constraints with status-based monitoring systems. The stability of coordination, measured by progress volatility, turns out to be one of the distinguishing factors of the quality of execution at different project statuses, and human resource analyses demonstrate the heterogeneous patterns of task advancement associated with allocation and sequencing practices. A compound managerial sustainability***

***proxy that combines completion performance, cost variance allows the relative benchmarking of projects in varied conditions. The results indicate that data-driven and visually comprehensible performance representations can be useful in supporting integrated governance and informed decision-making in complex-built environment projects.***

**KEYWORDS:** Integrated project management; sustainable infrastructure; project governance; execution analytics; built environment.

## 1. Introduction

The architectural and civil engineering projects are being more and more presented in the context of complicated organizational and institutional environment when the quality of performance is determined not only by the quality of technical design but also the effectiveness of the project governance, coordination, and control of the project execution. These information fragmentation and poor integration across professional boundaries have been traditionally identified as a major impediment to trustworthy project delivery and value creation over the long term in the architecture, engineering, and construction (AEC) field (Shen et al., 2010). With the growth in scale and socio-economic importance of infrastructure systems, integrated project management has become a key process by which the built environment is planned, delivered, and maintained. In this context, sustainability of infrastructure development is not limited to the environmental performance but also to the managerial and operational circumstances that can allow the stable implementation and responsible use of resources. Studies in construction project management have been focusing on the need to determine sustainability indicators capable of reflecting the governance effectiveness, financial discipline and project execution reliability at project level (Fernandez-Sanchez and Rodriguez-Lopez, 2010). Infrastructure wise, sustainable results are directly related to the way in which project management practice can bridge short term delivery goals with long term asset value and organizational sustainability (Kumaraswamy, 2011).

Although these issues have become more and more recognized, the operationalization of integrated project management to assess sustainability is not that easy. According to the empirical research, it can be stated that infrastructure sustainability is highly dependent on the project management practices that stabilize the coordination, minimize the uncertainty of the execution, and synchronize the administrative controls with the on-site progress (Xue et al., 2018). Nevertheless, most of the assessments are based on conceptual models or individual case studies that provide little information about the dynamics of task-level execution that can be generalized to project-level performance patterns across the various types of projects and governance settings. The development of digital technologies has provided new possibilities to fill this gap. It has been demonstrated that the combination of building information modeling (BIM) and project management systems can improve the coordination of the lifecycle and managerial transparency, assuming that the data on the execution are systematically analyzed and interpreted (Wang and Chen, 2023). Most recently, the intersection of BIM and artificial intelligence has further brought to light the importance of the data-based and visually understandable analytics in facilitating informed decision making and active governance in construction management (Pan & Zhang, 2023).

To address this, the current study formulates a data-driven analytic framework to analyze integrated project management strategies in the development of sustainable architectural and civil engineering infrastructure. The study assesses the pattern of financial deviation, alignment of task completion with managerial status and stability in coordination and human resource execution dynamics by consolidating the execution data at the task level into project-level performance indicators. The results add to a governance-based conception of sustainability in project delivery and show that analytical representations of project execution data may be used in integrated management within the built environment.

## 2. Literature Review

### 2.1 Integrated project management in architectural and civil engineering contexts

The value of integrated project management approaches has been given more importance in recent scholarship in dealing with the organizational and managerial complexity of architectural and civil engineering projects. Integrated delivery frameworks are considered to be critical tools of harmonizing various professional fields, minimizing fragmentation, and enhancing coordination at project stages. The literature on sustainable urban and infrastructure development emphasizes that the technical performance of the architectural design, civil engineering implementation, and landscape planning can be improved by well-coordinated integration to increase the level of governance coherence and long-term socio-economic value (Wimalasena et al., 2025; Zhou, 2024).

Project management often presents integration as a reaction to the ongoing delivery problems in construction, such as cost overruns, coordination issues, and a lack of fit between planning and execution. The systematic reviews of the construction project management practices point out the fragmented governance framework and poor coordination mechanisms as the common obstacles to the sustainable project performance, especially in the case of the large-scale infrastructure projects

(Misnan et al., 2024). These issues highlight the necessity to have management practices that run along organizational, disciplinary, and operational lines.

### 2.2 Sustainability-oriented project management and infrastructure delivery

The literature on sustainable project management is developing to acknowledge that managerial practices in infrastructure projects determine sustainability outcomes as much as environmental design strategies. One of the studies into infrastructure sustainability as a project management issue highlights the importance of governance frameworks, decision-making, and delivery control in ensuring sustainable delivery results (Xue et al., 2018). This view makes sustainability a capability of an organisation, a stability in execution and alignment of long-term values but not an environmental performance measure.

Some of the studies build on this argument by emphasizing on integrated management systems and governance structures that inculcate sustainability principles in project delivery processes. Integrated management system (IMS) solutions have been suggested as a tool that can be used to integrate quality, safety, environmental, and project management goals within a single governance framework, which would increase consistency and responsibility in construction projects (Waqar et al., 2025). On the same note, studies on sustainable infrastructure delivery emphasize the need to incorporate sustainability concepts in decision-making models that define project implementation processes through project planning to project completion (Moshood et al., 2025).

### 2.3 Project–asset integration and lifecycle governance

A critical literature is of the view that project delivery should be connected with long-term asset management in order to deliver sustainable built infrastructure. Research on integrated project and asset management states that sustainability relies on the continuity of the project implementation and asset operation, and early management decisions have a long-term impact on lifecycle performance (Fuzhan Nasiri et al., 2014). This integration school of thought does not focus on short term project deliverables but rather the long term governance and value creation.

Lifecycle-based studies also indicate that the infrastructure sustainability is undermined when the project management practices focus on the speed of delivery or cost reduction at the cost of coordination stability and operational availability. In comparison, governance frameworks incorporating project and asset factors promote more robust and flexible infrastructure systems, especially in the complex urban setting.

### 2.4 Digital technologies, BIM, and data-driven coordination

Digital technologies are increasingly becoming important in facilitating integrated project management. The studies of BIM-based integration prove that digital models may serve as coordination platforms, which synchronize design, construction, and managerial actions throughout the project life cycle (Liu et al., 2018). Nevertheless, the success of such integration is determined by the presence of digital tools that are accompanied by managerial procedures that transform data into governance actionable information.

Recent studies address how BIM can be combined with more modern digital technologies, such as artificial intelligence and parametric design methods, to enable predictive and adaptive project management. The analysis of BIM-AI integration reviews points to the possibility of data-driven analytics to improve decision-making, resource allocation, and execution monitoring in the construction management (Pan and Zhang, 2023). Simultaneously, parametric and forward-design methodology research in the field of infrastructure engineering highlights the role of digital integration in coordinating, making flexible, and sustainable complex engineering systems (Wu et al., 2025).

### 2.5 Organizational competitiveness and resilience through sustainable management

In addition to project-specific results, sustainable project management has been associated with organizational performance and resilience in general. Empirical research on the post-pandemic construction environment shows that those organizations that embrace sustainability-based approaches to project management are in a better position to sustain a competitive edge and adjust to systemic shocks (Bageis et al., 2023). These results support the perception that integrated and sustainable management practices are involved in organizational learning, flexibility, and sustainability.

The additional studies on disaster resilience in civil engineering further provide support to the significance of the quality of governance and managerial integration in the development of safe and sustainable communities. Disaster-resilient infrastructure reviews underline the fact that sustainability cannot be discussed without the ability of project management systems to predict, absorb, and react to uncertainty by coordinated action (Okem et al., 2024).

### 2.6 Research gap and positioning of the present study

Although the literature available has been able to offer abundant conceptual information on the topic of integrated project management, sustainability, and digital coordination, there are a few gaps. To start with, the majority of the studies are conceptual frameworks or qualitative case studies that provide a little evidence on the dynamics of task level execution aggregating into project level sustainability performance. Second, there is a dearth of comparative studies in the literature on project types and categories of governance status, especially in terms of standardized, data-based performance indicators. Third, there is comparatively little empirical research on the role of visual and analytical representations of execution data as governance tools in the research on architecture and civil engineering.

This research fills these gaps, by subjecting a quantitative, execution-based analytical model to task-based project management data, to allow systematic comparison of financial discipline, execution progress, coordination stability, and sustainability-oriented performance in a wide range of architectural and civil engineering project settings.

## 3. Methodology

### 3.1 Research design and analytical approach

This paper uses a quantitative, data-driven analytical methodology to explore the practice of integrated project management in the context of architectural and civil engineering infrastructure development. The conceptualization of sustainability is operational and managerial, focusing on the reliability in the execution, cost governance, stability of coordination and efficiency in the delivery instead of the narrow interpretation of environmental performance indicators. This view is in line with the modern research in architectural management and infrastructure governance, in which sustainable results are becoming more and more associated with organizational processes, project controls, and decision-making structures throughout the project life cycle.

The design of the methodology builds on a hierarchical analytical scheme in which the data on task-level executions are systematically converted into project-level performance measures. The structure allows exploring the way in which the characteristics of the micro-scale task execution are summed up into macro-scale patterns applicable to assessing the sustainability of infrastructure delivery in various types of projects and managerial scenarios.

### 3.2 Data source, structure, and preparation

The empirical study relies on an open project management data set including task-level data related to architectural and civil engineering projects obtained in the Hugging Face repository (Vans, 2021). The dataset is composed of 300 observations of tasks that are spread over various projects that can be characterized as a variety of renovation, construction, infrastructure, innovation, and maintenance-related developments.

Every observation is related to one task and consists of project descriptors, managerial classifications, and execution measures. Project variables describe contextual and organizational data like project type, location, time, priority and announced project status whereas task variables record execution status, people allocation, time spent on the project, budget plan, actual cost and level of progress.

All temporal variables were converted to a consistent datetime format before analysis to make sure that all observations were represented in time in a consistent manner. Variables that involve execution such as budget, actual cost, number of hours spent, and progress were represented in numbers to provide consistency in calculations. Integrity check ensured complete population of all the variables and structural consistency across observations. Table 1 is a summary of the variables in the dataset and their analytical functions.

**Table 1. Dataset variables and analytical roles**

| Category | Variables | Analytical role |
|---|---|---|
| Project context | Project ID, Project Name, Project Type, Location | Project identification and comparative grouping |
| Temporal attributes | Start Date, End Date | Temporal standardization and execution sequencing context |
| Managerial attributes | Project Status, Priority | Governance and execution classification |
| Task descriptors | Task ID, Task Name, Task Status | Task-level execution state |
| Human resources | Assigned To | Coordination and workload analysis |
| Execution metrics | Hours Spent, Budget, Actual Cost, Progress | Cost, effort, and completion assessment |

### 3.3 Task-level indicator construction

To reflect the dynamics of execution at the operational level, a number of task-level indicators were computed based on the initial data. Task cost variance was determined as the difference between actual cost recorded and planned budget, which gave an indication of financial deviation at the task level. Besides that, a binary cost overrun indicator was built to detect the tasks that were over their allocated budgets so that the overrun incidence could be assessed regardless of the magnitude of variance. The task progress was kept in its normalized type (01 scale) to assist in comparative assessment of progress in executing the project type, project status groups, and the assigned staff. Together, these indicators are able to capture financial control and execution progression attributes of task performance. Table 2 shows the computed task-level indicators that were used in the analysis.

**Table 2. Derived task-level indicators**

| Indicator | Definition | Interpretive purpose |
|---|---|---|
| Task cost variance | Actual Cost − Budget | Financial deviation from planned baseline |
| Cost overrun flag | Binary indicator of positive variance | Identification of budget breach events |
| Task progress | Progress (0–1) | Execution advancement |

### 3.4 Project-level aggregation and performance metrics

Since the study is managerial and sustainability-oriented, the task-level indicators were grouped together at the project level based on the project identifiers as the grouping key. Aggregation processes generated consolidated values of total planned budget, total actual cost recorded, cumulative cost variance, total effort spent, average task progress and task completion rate. The number of cost overruns cases per project was also calculated in totality to indicate exposure to budgetary risk.

These summary metrics allow making comparisons between projects and managerial categories in a systematic way, but they retain the informational richness of data on the execution of tasks at the task level. Mean progress and completion rate are seen as measures of execution maturity and delivery reliability as opposed to the measures of project success. Table 3 is a summary of the project level performance indicators used in the analysis.

**Table 3. Project-level performance indicators**

| Metric | Description |
|---|---|
| Total budget | Sum of planned task budgets |
| Total actual cost | Sum of recorded task costs |
| Total cost variance | Aggregate financial deviation |
| Total hours spent | Cumulative labor effort |
| Average task progress | Mean execution advancement |
| Completion rate | Proportion of fully completed tasks |
| Cost overrun count | Number of tasks exceeding budget |

### 3.5 Comparative analysis across project categories and governance status

The comparative analyses were made to analyse the variation in the characteristics of project performance with regard to the types of projects and the category of managerial status. The analysis of cost variance distributions was performed to establish the pattern of systematic financial behavior in various types of architectural and civil engineering development. The rates of tasks completion were compared against the announced project status in order to determine the correspondence between administrative classifications and actual execution results. The measure of coordination stability was the progress variability, which was the standard deviation of the task progress in categories of project status. An increase in dispersion is indicative of an imbalance in the progress of tasks and possible difficulty in coordination, and a decrease is indicative of greater coordination among tasks. Taken together, these comparative studies give an understanding of the effectiveness of governance, predictability of execution, and coherence of organizations in the context of projects.

### 3.6 Human resource coordination and execution patterns

To investigate the issue of human coordination in integrated project management, the distributions of tasks progress were studied among the assigned personnel. The disparity in the median progress levels and distribution spread illustrates the difference in the progress of work and the consistency of its execution among the team members. These differences are seen as manifestations of task assignment, sequencing and managerial assignment practices as opposed to direct individual performance measurements. This analysis is an addition to project-level performance assessment as it relates the results of execution to the organizational and coordination structures, which are the core of sustainable project delivery in architectural and civil engineering settings.

### 3.7 Composite managerial sustainability proxy

The study proposes a composite managerial sustainability proxy that combines execution reliability and financial discipline in the absence of direct environmental performance indicators. Minmax normalization was used to normalize two project level indicators: task completion rate and total cost variance to the same common scale so that they could directly compare them. The composite efficiency score was developed as the result of the combination of the normalized completion performance and normalized cost variance whereby projects that showed comparatively better completion results and lower undesirable cost variance were rated higher. The metric is clearly considered to be a relative, dataset-specific measure aimed at helping to interpret the performance of integrated project management comparatively, but not to give an absolute sustainability measure.

### 3.8 Methodological scope and limitations

The methodological approach is limited to the range of the available dataset as it focuses on managerial and executional variables and not on the environment or life-cycle performance indicators. Consequently, sustainability is operationalised in terms of governance quality, stability of coordination and efficiency in delivery proxies. In spite of these shortcomings, the methodology offers a clear and repeatable framework of investigating integrated project management practices in the development of architectural and civil engineering infrastructure.

## 4. Results

### 4.1 Descriptive characteristics of project-level performance

The empirical study is founded on 300 observations on the tasks level which were summarized to 100 different architectural and civil engineering projects. Table 4 reports the summary statistics of the key project-level indicators, namely, budget allocation, realized cost, and execution progress.

**Table 4. Descriptive statistics of project-level financial and execution indicators**

| Statistic | Total Budget | Total Actual Cost | Average Task Progress |
|---|---|---|---|
| Count | 100 | 100 | 100 |
| Mean | 16,872.8 | 5,184.2 | 0.636 |
| Std. deviation | 4,265.7 | 5,123.5 | 0.193 |
| Minimum | 8,119 | 0 | 0.207 |
| 25th percentile | 13,913.5 | 0 | 0.503 |
| Median | 16,716.0 | 3,725.5 | 0.642 |
| 75th percentile | 19,549.0 | 8,529.0 | 0.768 |
| Maximum | 27,851 | 23,091 | 1.000 |

Table 4 demonstrates that project budgets are highly varied with variation of 18,732 monetary units, 27,851 monetary units and a mean project budget of 16,872.8. Conversely, the actual cost realization is significantly less with a mean of 5,184.2 and lower quartile value of zero, implying that a considerable percentage of the projects were yet to realize financial expenditure at the point of observation. Nonetheless, overall task advancement is at a fairly high level (mean = 0.636 on a normalized 0-1 scale), which implies that the execution activity often comes before formal cost realization. This deviation creates a significant contextual requirement on the interpretation of cost variance and efficiency results in further analyses.

### 4.2 Aggregated project performance metrics

To explain the format of the aggregated dataset on which all further analyses will be conducted, Table 5 provides an exemplar of aggregated project-level performance indicators based on task-level data. The table reports total budget, total actual cost, cost variance, cumulative hours worked, average task progress, completion rate and the rate of cost overruns.

**Table 5. Project-level aggregated performance metrics (illustrative subset)**

| Project ID | Total Budget | Total Actual Cost | Cost Variance | Total Hours | Avg. Progress | Completion Rate | Cost Overrun |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P001 | 18,463 | 1,011 | −17,452 | 21 | 0.600 | 0.333 | 0 |
| P002 | 18,545 | 0 | −18,545 | 78 | 0.313 | 0.000 | 0 |
| P003 | 17,559 | 16,856 | −703 | 43 | 1.000 | 1.000 | 0 |
| P004 | 19,147 | 3,369 | −15,778 | 72 | 0.910 | 0.333 | 0 |
| P005 | 12,812 | 2,643 | −10,169 | 25 | 0.607 | 0.333 | 0 |

The selected projects demonstrate a high level of heterogeneity in the pattern of execution and cost realization. As an illustration, project P003 shows full execution of tasks with low variance of cost whereas Project P002 shows high labor input and incomplete execution with no actual cost recorded. In all the presented projects, the value of cost variance is negative, which supports the fact that the dominant majority of the dataset is characterized by delayed or incomplete cost reporting, but not by systematic overspending.

### 4.3 Cost variance and overrun behavior across project types

The project-level cost variance distributions in the project categories are depicted in Figure 1. In all types of projects, the median cost variance values are negative and this confirms that cost realized is usually lower than the planned budgets. Construction projects have the greatest dispersion and the most extreme negative outliers, which implies that the time of cost realization varies significantly. Infrastructure projects, on the contrary, exhibit smaller distributions, indicating comparatively stable financial implementation behavior.

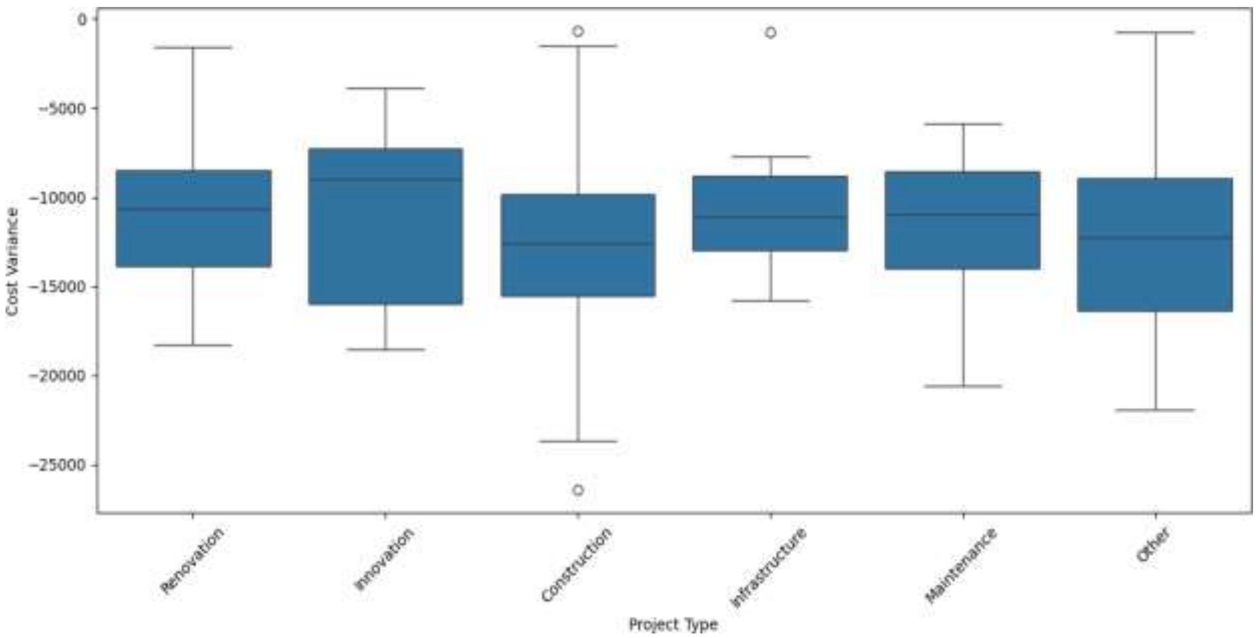


**Figure 1. Cost variance distribution by project type**

In addition to the magnitude of the variance, Figure 2 also shows the average cost overrun rates by type of project. Overall overrun rates are low, but the highest mean values and variability are observed in projects that are categorized as Other, then infrastructure and construction projects. In renovation and maintenance projects the overruns are low meaning that there is a tight control on costs or postponed realization of costs.

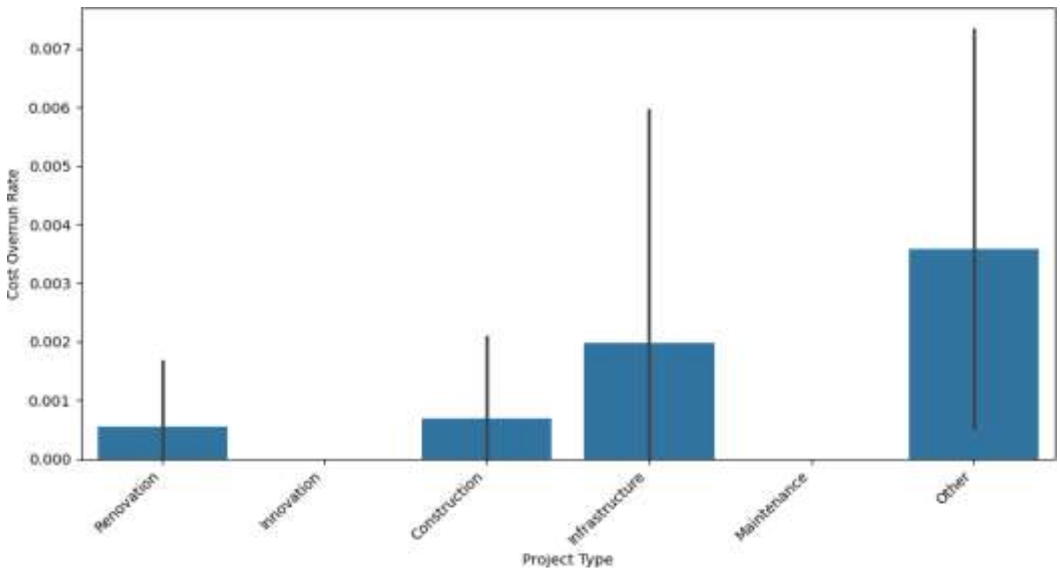


**Figure 2. Cost overrun rate across project types**

### 4.4 Project status and task completion alignment

Figure 3 analyzes the relationship between the stated project status and the actual performance in terms of accomplishing tasks. There are no significant differences in average completion rates between completed and On Hold projects (around 0.33), whereas the values of Behind projects are somewhat lower. Remarkably, the lowest completion rate can be observed in projects that are categorized as On Track; it is about 0.21. This paradoxical trend shows that there is low correspondence between the labels of administrative project status and actual task performance, which implies that status labels can be a reflection of planning intent, but not actual performance results.

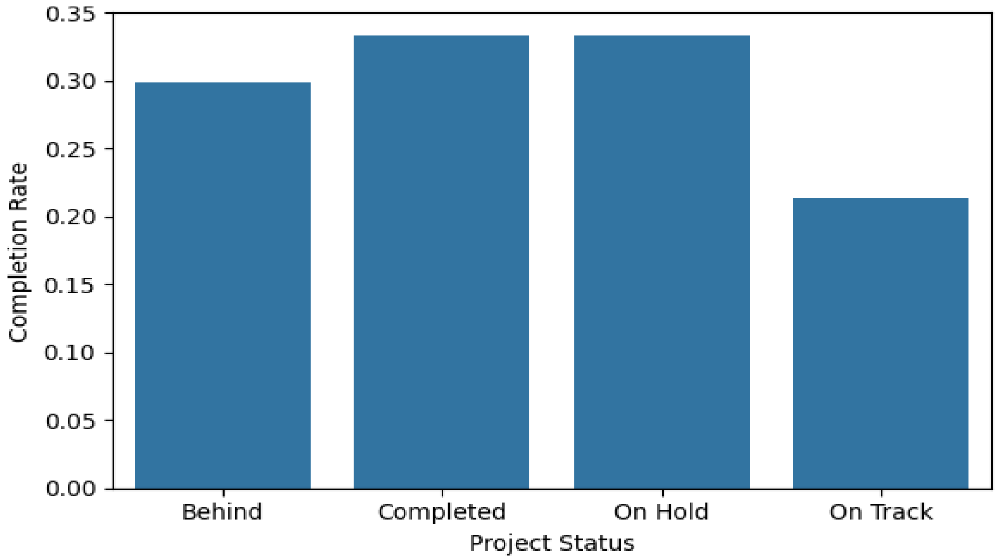


**Figure 3. Task completion rate by project status**

### 4.5 Coordination stability and progress volatility

Progress volatility was used to measure coordination stability, and it was the standard deviation of task progress in each project status category. Completed projects have the highest variability of progress as shown in Figure 4, then the Behind projects. On Track projects are the least volatile, meaning that they have more coordinated task progress even though they have lower average completion rates. These results indicate that administrative completion does not always mean that tasks are carried out in a coordinated manner, and projects that are termed On Track might be more concerned with consistency than speedy task completion.

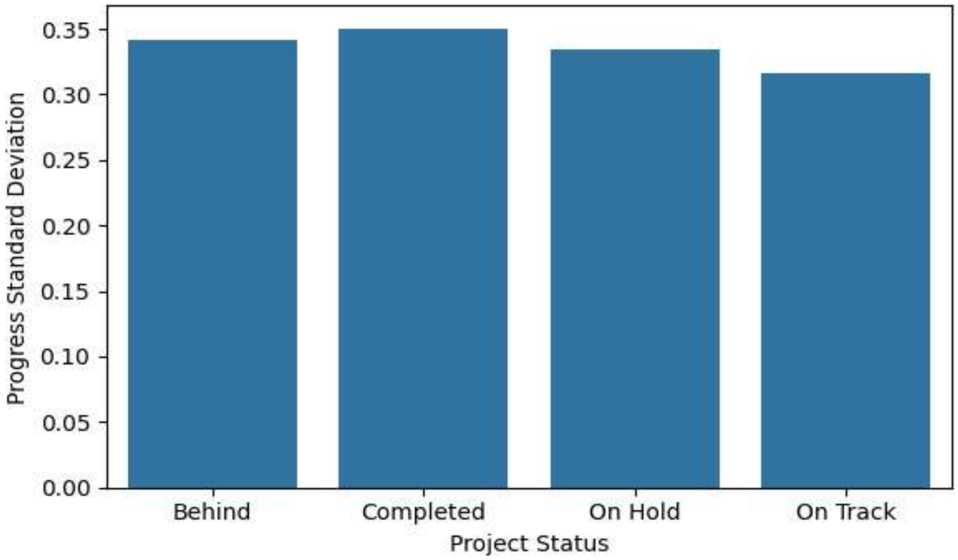


**Figure 4. Progress volatility (standard deviation) by project status**

**4.6 Human resource coordination and task execution patterns**

Figure 5 shows how personnel assigned to tasks will distribute them. The findings indicate a significant heterogeneity of median levels of progress and variability among individuals. There are those members of staff who exhibit focused distributions at higher progress values and those staff members who have wider distributions that cover both early and late tasks. These trends indicate the effects of task allocation, sequencing practices on the result of execution and demonstrate the significance of human coordination within an integrated project management setting.

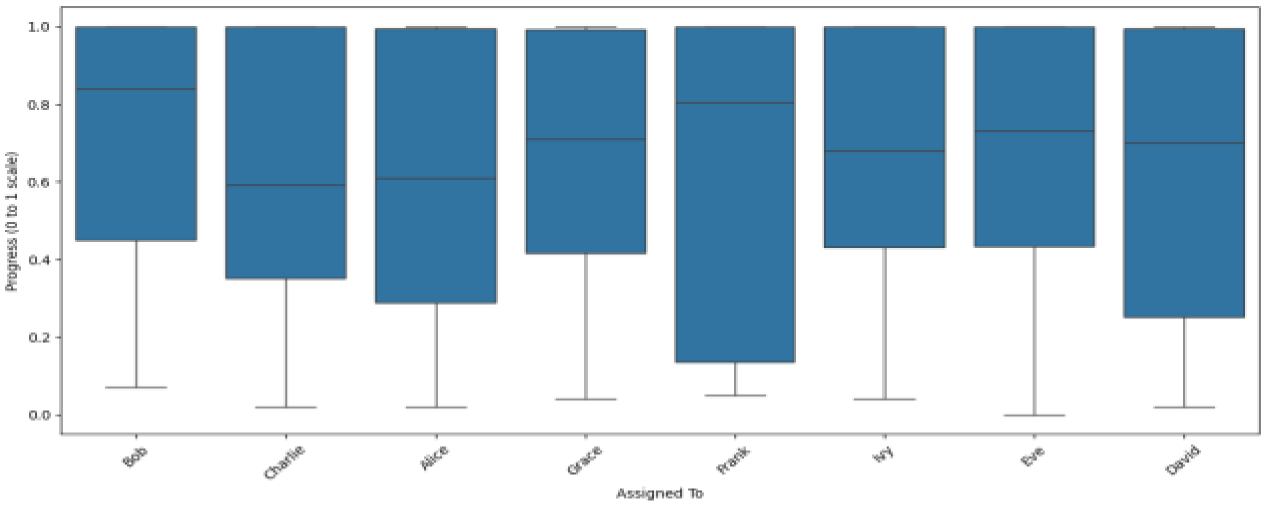


**Figure 5. Task progress distribution by assigned personnel**

**4.7 Task execution states across project types**

Figure 6 displays the distribution of the task execution states (Pending, In Progress, and Completed) per project type. Renovation and construction projects have relatively balanced distributions, which is characterized by the constant turnover of tasks. The infrastructure works have a higher percentage of the tasks accomplished, which implies a higher level of execution. Conversely, other projects are characterized by a strong concentration of outstanding tasks, which is early development or backlog.

SCIENTIFIC CULTURE
www.sci-cult.com
SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 8822-8835
Open Access. Online & Print

DOI: 10.5281/zenodo.12426872

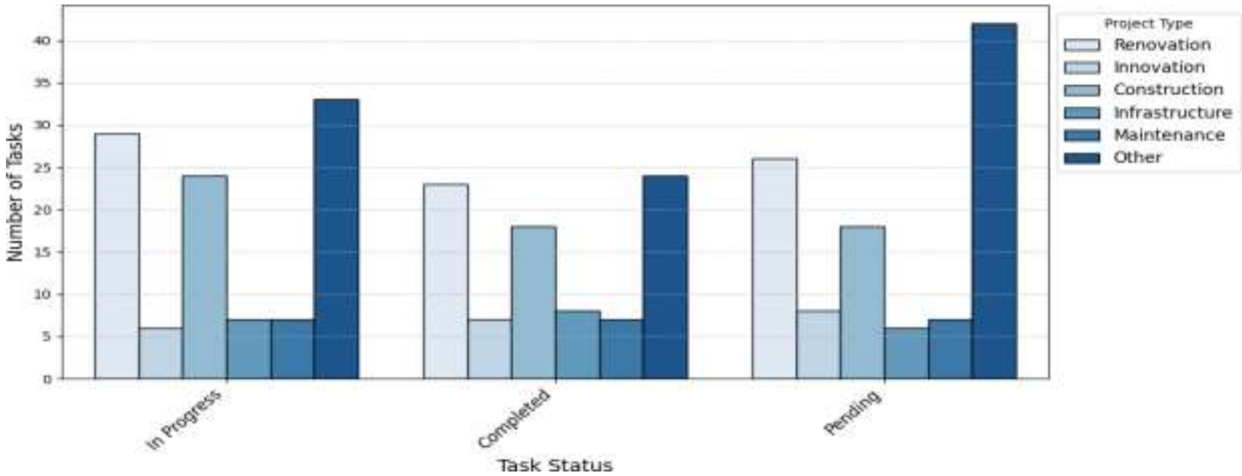


**Figure 6. Task status distribution across project types**

### 4.8 Effort expenditure and cost realization relationship

Figure 7 shows the correlation between the total project hours spent and the actual cost recorded. The weak and non-linear relationship between financial realization and effort expenditure is depicted in the scatter plot. Many projects have large amounts of labor hours which have not been recorded as cost, which confirms the observation that cost reporting is frequently behind the execution progress. This decoupling goes further to suggest the interpretation that negative cost variance in the dataset is more of reporting dynamics than inefficiency or waste.

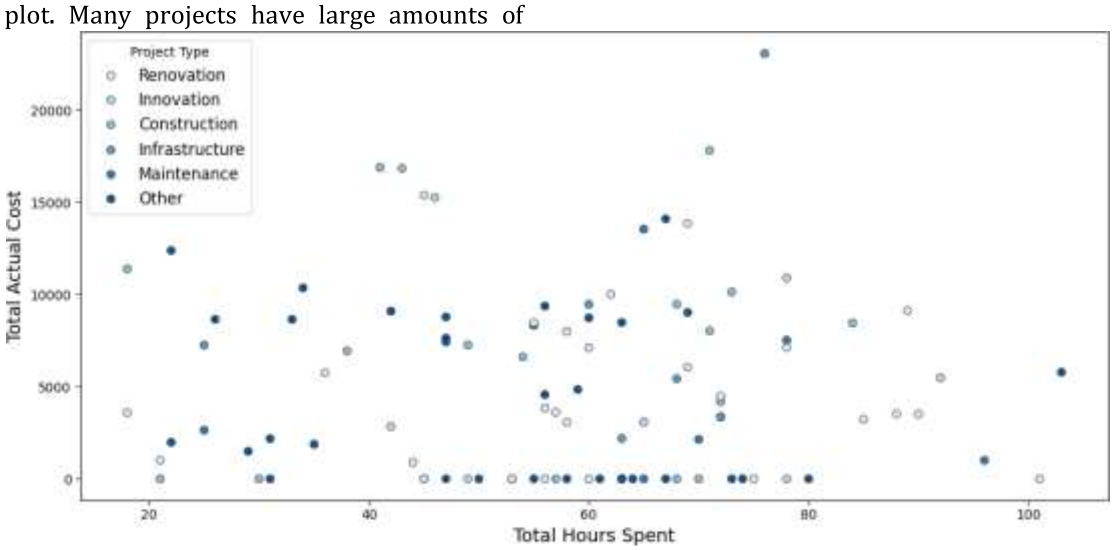


**Figure 7. Total project hours spent versus total actual cost**

### 4.9 Composite sustainability-oriented performance ranking

Composite managerial sustainability proxy was developed by combining normalized completion rates of tasks and normalized cost variance at the project level. Table 6 lists the top five projects in terms of this composite score.

**Table 6. Top-ranked projects by composite managerial sustainability proxy**

| Project ID | Completion Rate | Sustainability Efficiency Score |
|---|---|---|
| P043 | 0.667 | 0.059 |
| P090 | 0.333 | 0.038 |
| P033 | 0.667 | 0.037 |
| P039 | 0.667 | 0.036 |

| | | |
|---|---|---|
| P012 | 0.667 | 0.022 |

Project P043, P033, P039 and P012 have the advantage of high task completion rates as well as favourable cost variance profiles, whereas Project P090 has a high ranking because it has high cost performance despite low completion. The composite indicator therefore represents the trade-offs between execution progress and financial discipline, which provides a relative measure of sustainability-oriented project management performance.

**Discussion**

This study provides empirical evidence on the role of integrated project management practices in shaping sustainability oriented solutions in the delivery of architectural and civil engineering infrastructure under the conditions of sustainability as interpreted in terms of managerial and operational performance. The negative cost variance prevalence in all the project types and the comparatively high levels of task execution progress suggest that there is a systematic decoupling between reporting and execution activity of finance. Instead of indicating excessive spending, this trend indicates a lag in or incompleteness of cost realization, which is consistent with the fact that operational and financial information in digitally mediated project settings is generally difficult to align. This result is consistent with the more recent findings that project management systems based on digital technology tend to be incapable of developing an integrated operational perspective by incorporating execution data, cost tracking, and governance decision-making into a unified operational perspective, even as these systems are increasingly used in the AEC sector (Chen et al., 2025).

The noted discrepancy between the reported project status and the real tasks completion also highlights the limitation of governance in integrated project environment. The completion rates of projects that were classified as being On Track were lower than those projects that were classified as being Completed or On Hold and this suggests that administrative classifications may focus on planning intent rather than the reality of execution. These inconsistencies resonate with the issues presented in the literature on sustainable infrastructure management, where the alignment of sustainability objectives and management intentions to uniform operational results is still a problematic issue (Elhamahmy et al., 2025). The results indicate that status-based reporting is not enough in measuring sustainability-oriented performance without the execution-level indicators.

The coordination stability measured by the variability of progress offers further understanding of integrated management effectiveness. The more the progress volatility in the projects, the more the synchronized patterns of execution were observed, despite the overall completion levels being moderate. This helps to argue that sustainable infrastructure delivery is not only based on the speed with which tasks are done but also on consistent coordination paths that minimize uncertainty and fragmentation of execution. Such stability is essential in terms of an integrated project-asset management approach, where a short-term decision on delivery should be made to sustain long-term asset performance and continuity of the organization (Fuzhan Nasiri et al., 2014). The findings support the perception that governance coherence and coordination reliability are two key elements of managerial sustainability in the development of infrastructure.

The human aspect of integration is identified by the analysis of the distributions of the tasks progress among the designated personnel. There is a lot of heterogeneity in the execution patterns implying that the distribution of tasks, sequence, and responsibility structures play a significant role in determining the performance outcomes. This observation is in line with the general studies on BIM-enabled and digitally supported project management, which highlights that the technological integration per se does not ensure efficient coordination without the proper organizational practices and roles definitions (Kaur et al., 2025). Integration thus becomes a socio-technical state which is mutually determined by the data systems and managerial systems.

The composite managerial sustainability proxy created in this paper demonstrates the way in which the reliability in execution and financial discipline could be integrated into a relative benchmarking instrument to gauge governance. Although it is explicitly dataset-specific, this proxy shows how analytical and visual representations can be used to help make comparative assessment between heterogeneous project settings. These practices resonate with the modern views of the project management education and practice that focus on experiential and data-driven models of comprehending the complex dynamics of delivery (Zhang et al., 2019). These representations enhance more informed managerial evaluation and decision-making through making the patterns of execution and conditions of governance visible and interpretable. It must be noted that there are several limitations. These limitations on sustainability assessment to managerial and operational levels are caused by lack of environmental and lifecycle indicators, and the cross-sectional character of the data does not provide information on the dynamics over time. Future studies ought to incorporate the environmental performance indicators, longitudinal performance data, and the BIM generated data to bring the framework to the multidimensional system of sustainability assessment. The enlargement of the analytical method to real-time digital dashboards and decision-support systems would enhance the position of visual analytics in integrated and sustainable infrastructure governance.

**Conclusion**

This paper shows that the operationalization of integrated project management strategies can be used to measure sustainability-oriented performance in the development of architectural and civil engineering infrastructure using managerial and execution-based indicators. The analysis can be used to identify systematic trends of financial deviation, coordination stability and governance misalignment that would otherwise be hidden in traditional project reporting by aggregating task-level execution data into project-level performance measures. The findings show that negative cost variance is often an indicator of late cost realization and not inefficiency, whereas discrepancies between proclaimed project status and actual completion of tasks are indicative of shortcomings in status-based governance systems. Progress volatility and human resource coordination analysis also highlights the relevance of aligned execution and consistent coordination frameworks towards sustainable project delivery. The composite managerial sustainability proxy that will be offered in this study offers a clear and repeatable way of benchmarking projects in terms of reliability in execution and financial discipline. Despite the fact that sustainability, in this case, is viewed through the prism of management because of the lack of data, the analytical framework provides the basis of including environmental and lifecycle indicators in future studies. In general, the paper is relevant to the further understanding of the way in which data-driven representations of performance may be used to inform decisions and integrated governance in managing complex built environment projects.

**References**

1. Bageis, A. S., Waqar, A., Hamah Sor, N., Almujibah, H., Qureshi, A. H., Jagadesh, P., ... & Benjddou, O. (2023). Evaluation of factors affecting the competitive advantage of organizations in establishing sustainable project management post covid-19. *Journal of Engineering*, *2023*(1), 3529313.
2. Chen, X., Chang-Richards, A. Y., Ling, F. Y. Y., Yiu, T. W., Pelosi, A., & Yang, N. (2025). Digital technology-enabled AEC project management: practical use cases, deployment patterns and emerging trends. *Engineering, Construction and Architectural Management*, *32*(6), 4125-4154.
3. Elhamahmy, A., Gohar, H. T. H., & Galal, A. (2025). Sustainable project management in renewable energy and infrastructure projects: Challenges and opportunities. *International Journal of Engineering Research & Technology*, *14*(05).
4. Fernández-Sánchez, G., & Rodríguez-López, F. (2010). A methodology to identify sustainability indicators in construction project management—Application to infrastructure projects in Spain. *Ecological Indicators*, *10*(6), 1193-1201.
5. Fuzhan Nasiri, D., KW Wong, K., Kumaraswamy, M., Mahesh, G., & YY Ling, F. (2014). Building integrated project and asset management teams for sustainable built infrastructure development. *Journal of Facilities Management*, *12*(3), 187-210.
6. Kaur, R., Mwambegele, B. J., Abraham, A. G., Basheer, S. A., & Garia, S. (2025). A comprehensive review on building information modelling (BIM), its implementations and applications. *Discover Civil Engineering*, *2*(1), 177.
7. Kumaraswamy, M. (2011). integrating "infrastructure project management" with its "built asset management". *Built environment project and asset management*, *1*(1), 5-13.
8. Liu, Y., van Nederveen, S., Wu, C., & Hertogh, M. (2018). Sustainable infrastructure design framework through integration of rating systems and building information modeling. *Advances in Civil Engineering*, *2018*(1), 8183536.
9. Misnan, M. S., Ismail, M. Z., & Yan, T. J. (2024). Construction project management issues and development in current for future construction project: challenges and prospects in sustainable project management. *International Journal of Research and Innovation in Social Science*, *8*(2), 1997-2011.
10. Moshood, T. D., Rotimi, J. O., & Wajiha, S. (2025). Sustainability principles in infrastructure project

delivery: establishing the broader implementation strategies for decision-making. *Construction Innovation*, *25*(5), 1370-1411.

11. Okem, E. S., Nwokediegwu, Z. Q. S., Umoh, A. A., Biu, P. W., Obaedo, B. O., & Sibanda, M. (2024). Civil engineering and disaster resilience: A review of innovations in building safe and sustainable communities. *International Journal of Science and Research Archive*, *11*(1), 639-650.
12. Pan, Y., & Zhang, L. (2023). Integrating BIM and AI for smart construction management: Current status and future directions. *Archives of Computational Methods in Engineering*, *30*(2), 1081-1110.
13. Shen, W., Hao, Q., Mak, H., Neelamkavil, J., Xie, H., Dickinson, J., ... & Xue, H. (2010). Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. *Advanced engineering informatics*, *24*(2), 196-207.
14. Vans, J. (2021). *Project Management* [Data set]. https://huggingface.co/datasets/JohnVans123/ProjectManagement
15. Wang, T., & Chen, H. M. (2023). Integration of building information modeling and project management in construction project life cycle. *Automation in Construction*, *150*, 104832.
16. Waqar, A., Nisar, S., Muddassir, M., & Benjeddou, O. (2025). An integrated management system (IMS) approach to sustainable construction development and management. *Journal of Infrastructure Intelligence and Resilience*, *4*(1), 100126.
17. Wimalasena, S., Weerakoon, T. G., & Wimalasena, J. (2025). Integrated approaches to sustainable urban development: the synergy between landscape architecture and civil engineering. *Mokslas–Lietuvos ateitis/Science–Future of Lithuania*, *17*.
18. Wu, S., Ramli, M. Z., Ngian, S. P., Qiao, G., & Jiang, B. (2025). Review on parametric building information modelling and forward design approaches for sustainable bridge engineering. *Discover Applied Sciences*, *7*(2), 127.
19. Xue, B., Liu, B., & Sun, T. (2018). What matters in achieving infrastructure sustainability through project management practices: A preliminary study of critical factors. *Sustainability*, *10*(12), 4421.
20. Zhang, J., Xie, H., Schmidt, K., Xia, B., Li, H., & Skitmore, M. (2019). Integrated experiential learning–based framework to facilitate project planning in civil engineering and construction management courses. *Journal of professional issues in engineering education and practice*, *145*(4), 05019005.
21. Zhou, J. (2024). Synergizing architectural design, structural restoration, and civil engineering for sustainable urban development. In *SHS Web of Conferences* (Vol. 192, p. 01014). EDP Sciences.