



The Impact of Overlapping Phases in EPCC Projects on the Accuracy of 4D BIM (Time) and 5D BIM (Cost): A Literature Review

Nadiatul Huliyah¹, Bambang Endro Yuwono¹

¹Master of Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Universitas Trisakti, Jakarta, Indonesia

*Corresponding Author: Nadiatul Huliyah

E-mail: 151012400001@std.trisakti.ac.id



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Abstract

Engineering, Procurement, Construction, and Commissioning (EPCC) projects often apply overlapping phases to accelerate project completion. This strategy allows procurement, construction, or commissioning to start before the preceding phase is fully completed. However, design, material, schedule, and cost information may continue to change and affect the accuracy of 4D and 5D Building Information Modeling (BIM). This study explains the effect of EPCC phase overlap on the time accuracy of 4D BIM and the cost accuracy of 5D BIM and describes the role of BIM in project control. A literature review was conducted using 38 journal articles covering fast-track construction, 4D BIM, 5D BIM, scheduling, procurement, quantity take-off, interoperability, and cost control. The findings show that overlap can reduce BIM accuracy when design changes, procurement status, field progress, and cost information are not updated promptly. The accuracy of 4D BIM is affected in work sequence, activity relationships, duration, progress, and completion time. The accuracy of 5D BIM is affected in quantities, prices, rework costs, scope changes, and final cost forecasts. Nevertheless, BIM remains important because it enables project teams to identify the time and cost consequences of changes more quickly. BIM accuracy can be maintained through regular model updates, consistent project data, integration of models with schedule and cost information, and coordination among EPCC phases.

Introduction

EPCC projects integrate engineering, procurement, construction, and commissioning into a single, interconnected project delivery process (Arifuddin & Abdurrahman Engineerin, 2026; Jaafar & Zainuddin, 2020; Prasetya, 2026). outputs provide the basis for procurement, procurement status determines construction readiness, and construction completion governs testing and commissioning readiness. Consequently, changes in one phase can significantly affect subsequent phases, particularly in industrial, energy, and infrastructure projects characterized by multiple systems and work packages.

To accelerate project completion, many EPCC projects adopt a fast-track approach, in which activities from different phases are intentionally overlapped. Procurement may begin based on preliminary specifications, construction may proceed using released design packages before the entire design is finalized, and commissioning may be conducted on a system-by-system basis before all physical works have been completed. While the fast-track strategy offers opportunities for schedule reduction, it also increases uncertainty, coordination

requirements, design revisions, rework, and cost adjustments (Peña-Mora & Li, 2001; Peña-Mora & Park, 2001; Garrido Martins et al., 2023).

Building Information Modeling (BIM) has evolved into an integrated information management system that supports project coordination, visualization, planning, and control. The effectiveness of BIM depends on data quality, collaborative processes, information structure, and the organization's ability to maintain and update the model (Succar, 2009; Azhar, 2011; Bryde et al., 2013; Cao et al., 2015). 4D BIM integrates three-dimensional models with project schedules, whereas 5D BIM links the model with quantity and cost information.

Challenges arise when BIM models continue to rely on outdated designs or project status. Under overlapping conditions, design changes may occur after procurement or construction has already begun. Consequently, the 4D BIM schedule may display sequences and completion dates that no longer reflect actual project conditions, while 5D BIM may generate quantity and cost information based on a scope that has already changed. In addition, interoperability issues and inconsistencies in data structures among software platforms may further reduce information consistency (Laakso & Kiviniemi, 2012; Noardo et al., 2021; Pauwels et al., 2017).

Previous studies have examined the risks associated with fast-track delivery, the benefits of BIM, 4D modeling, progress monitoring, quantity take-off, and 5D BIM. However, research specifically investigating the direct relationship between overlapping EPCC phases and the accuracy of 4D and 5D BIM remains limited. Therefore, this study aims to: (1) describe the forms of phase overlap in EPCC projects; (2) analyze the effects of overlapping phases on the accuracy of 4D BIM and 5D BIM; and (3) explain the role of BIM in supporting project time and cost control.

Literature Review

Overlapping Phases in EPCC Projects

Overlapping phases refer to the execution of a subsequent project phase before the preceding phase has been fully completed. In EPCC projects, overlap may occur between engineering and procurement, engineering and construction, procurement and construction, as well as construction and commissioning. The degree of overlap varies across projects depending on schedule objectives, design maturity, material availability, contractual arrangements, and risk tolerance.

Although fast-track delivery can significantly reduce waiting time between project phases, its success depends largely on the quality of information exchange. Changes to upstream information after downstream activities have commenced may result in change orders, rework, sequence modifications, schedule delays, and additional costs. Dynamic planning approaches are therefore required because initial plans must continuously adapt to changes occurring during project execution (Peña-Mora & Li, 2001; Peña-Mora & Park, 2001). Research on fast-track project risks further indicates that the extent of phase overlap is directly associated with changes in the level of risk perceived by practitioners (Garrido Martins et al., 2023).

Within the engineering–procurement interface, the primary risk arises when purchasing activities begin before final specifications and quantities have been established. At the engineering–construction interface, design revisions may alter the sequence and scope of ongoing construction activities. At the procurement–construction interface, material or vendor delays may interrupt field operations. Finally, during the construction–commissioning interface, incomplete systems, documentation, or unresolved punch-list items may delay commissioning activities. Procurement-related risks in EPC projects can therefore propagate

throughout the project schedule and budget because of the complex interdependencies among stakeholders and work packages (Wang & Wang, 2022).

4D BIM and Schedule Accuracy

4D BIM integrates model objects with project activities and scheduling information. Its application has evolved beyond simple construction sequence visualization to include coordination, constructability review, project communication, progress monitoring, and schedule updating (Koo & Fischer, 2000; Heesom & Mahdjoubi, 2004; Hartmann et al., 2008; Rehman et al., 2025). Studies on 4D BIM implementation also emphasize the importance of system compatibility, user competency, and implementation processes (Gledson & Greenwood, 2016, 2017).

The accuracy of 4D BIM refers to the extent to which model objects, activities, dependency relationships, durations, dates, and progress information accurately reflect the latest project schedule and actual site conditions. Developing an accurate 4D schedule requires an appropriate level of detail, clearly defined model parameters, well-defined responsibilities, and consistent model updates (Doukari et al., 2022). If model objects are incorrectly linked to project activities, the resulting 4D visualization may appear complete while providing inaccurate scheduling information.

Furthermore, 4D BIM can be integrated with measurement technologies to compare planned and actual construction progress. The application of laser scanning, point clouds, and remote sensing technologies demonstrates that BIM can effectively support progress measurement and schedule updating (Turkan et al., 2012; Kim et al., 2013; Zhang & Arditi, 2013). During coordination meetings, 4D models also facilitate constructability reviews and promote a shared understanding of construction sequencing among project stakeholders (Staub-French & Khanzode, 2007; Boton, 2018).

5D BIM and Cost Accuracy

5D BIM integrates model objects with quantities, work classifications, unit prices, budgets, procurement commitments, actual expenditures, and estimated final costs. The system supports quantity take-off, cost estimation, change analysis, payment management, and cash flow control (Smith, 2014; Lu et al., 2016; Vigneault et al., 2020; Pishdad & Onungwa, 2024).

The accuracy of 5D BIM depends not only on the software's capability to calculate quantities automatically but also on object modeling practices, measurement rules, cost classification systems, unit price quality, and the currency of project scope information. Dedicated modeling guidelines for quantity take-off are essential to ensure that model information can be accurately translated into measurable quantities (Monteiro & Martins, 2013). Previous studies also identify challenges related to incomplete model objects, differences in measurement methodologies, software functionality, and data loss during model exchange (Alathamneh et al., 2024; Khosakitchalert et al., 2020).

In projects with overlapping phases, cost information often exhibits varying levels of certainty. Some values remain as allowances, others are based on vendor quotations, while some have already become committed costs. If these values are presented without distinguishing their respective status, 5D BIM may produce misleading cost representations. Therefore, effective 5D cost control in complex projects requires the integration of model structures, schedules, procurement information, cost data, and decision-making processes (Hussain et al., 2024; Cassandro et al., 2025).

The Role of BIM in EPCC Projects

BIM serves as an integrated platform for information exchange across multiple disciplines. Its value extends beyond three-dimensional visualization to its ability to integrate both

product and process information. Research combining BIM with Lean Construction principles demonstrates that visualization, information flow, coordination, and variation reduction can collectively improve project performance (Sacks et al., 2010).

Nevertheless, BIM implementation does not automatically guarantee project success. Its effectiveness may be constrained by organizational culture, unclear allocation of responsibilities, inadequate data standards, workforce readiness, and dependence on software platforms (Barlish & Sullivan, 2012; Miettinen & Paavola, 2014). Likewise, a highly detailed BIM model does not necessarily ensure accurate project information if the underlying data are not regularly updated. Therefore, in projects involving overlapping phases, the primary role of BIM is to capture, integrate, and communicate the impacts of project changes in a coordinated and timely manner.

Methods

This study employs a structured literature review methodology. The PRISMA 2020 guidelines were adopted as a general framework to enhance the transparency and traceability of the literature search and selection process. However, a meta-analysis was not conducted because the reviewed studies varied considerably in terms of research contexts, variables, and measurement indicators (Page et al., 2021).

The literature search was conducted using academic databases and scientific journal repositories with the following keywords: "EPCC overlap," "EPC fast-track," "overlapping construction phases," "4D BIM scheduling," "4D BIM progress monitoring," "5D BIM cost," "BIM quantity take-off," "BIM interoperability," and "EPC procurement risk." The review primarily focused on journal articles addressing project phase overlap, schedule management, cost management, procurement, design changes, and BIM-based information management.

The inclusion criteria comprised: (1) journal articles discussing fast-track project delivery or overlapping project phases; (2) studies on 4D BIM, scheduling, constructability, or progress monitoring; (3) studies on 5D BIM, quantity take-off, cost estimation, and cost control; and (4) studies addressing BIM interoperability and information quality. A total of 38 journal articles were selected as the primary references for this literature review.

The analysis was conducted by organizing the findings into three major themes: (1) forms of overlapping phases in EPCC projects, (2) the impact of phase overlap on the accuracy of 4D BIM and 5D BIM, and (3) the role of BIM in managing schedule and cost changes. Subsequently, 35 key journal articles were synthesized and summarized in an expert opinion matrix to illustrate the relationship between each reference and the focus of this study.

Results and Discussion

Forms and Impacts of EPCC Phase Overlap

The study results show that the impact of overlap varies by phase pair. Engineering–procurement overlap primarily affects specifications, quantities, lead times, and purchase commitment amounts. Engineering–construction overlap affects work sequences, scope changes, productivity, and rework. Procurement–construction overlap affects material readiness, implementation methods, and activity sequencing. Construction–commissioning overlap affects system readiness, testing, documentation, and handover time.

Table 1. Effect of EPCC phase overlap on time, cost, and the role of BIM

Type of Overlap	Primary Impact	Role of BIM 4D	Role of BIM 5D
Engineering–Procurement	Changes in specifications, quantities, vendors, and	Integrates procurement lead times and schedules	Differentiates budgets, quotations,

	procurement schedules may occur.	with construction activities.	commitments, and price changes.
Engineering–Construction	Design changes may alter the work sequence and result in rework.	Updates activities, dependencies, durations, and project milestones.	Calculates changes in quantities, productivity, and rework costs.
Procurement–Construction	Material delivery delays may postpone or alter the sequence of construction activities.	Displays material constraints and alternative work sequences.	Updates material, transportation, storage, and acceleration costs.
Construction–Commissioning	Systems may not be ready for testing because construction work or documentation is incomplete.	Displays system readiness, turnover status, and testing schedules.	Calculates testing, vendor, utility, and additional work costs.

The Impact of Overlapping Phases on 4D BIM Accuracy

Overlapping project phases accelerate the occurrence of information changes because downstream activities proceed while upstream information is still evolving. In 4D BIM, design modifications may alter model objects, work packages, activity relationships, material requirements, and construction methods. If these changes are not incorporated promptly, the model will continue to display sequences and schedule dates based on outdated information.

The primary impacts on 4D BIM accuracy include: (1) model objects being linked to incorrect activities; (2) predecessor–successor relationships no longer reflecting the actual construction sequence; (3) activity durations and schedule dates becoming inconsistent with the latest project conditions; (4) discrepancies between model progress and actual site progress; and (5) commissioning milestones failing to correspond with actual system readiness. Previous studies on the use of 4D BIM for coordination and progress monitoring indicate that the quality of project information depends heavily on maintaining up-to-date links between model objects and scheduling data (Koo & Fischer, 2000; Hartmann et al., 2008; Turkan et al., 2012; Doukari et al., 2022).

The degree of accuracy deterioration depends on both the number of project changes and the delay in updating the BIM model. Well-managed project overlap does not necessarily lead to inaccurate 4D models. 4D BIM can continue to provide reliable project information provided that engineering revisions, procurement status, and construction progress are updated more rapidly than subsequent project changes occur.

The Impact of Overlapping Phases on 5D BIM Accuracy

Within 5D BIM, design changes may affect quantities, material types, technical specifications, unit prices, productivity assumptions, and contractual scope. Overlap between engineering and procurement may result in discrepancies between model-based costs and purchase orders because the model may still rely on preliminary allowances or initial pricing assumptions. Likewise, overlap between engineering and construction may generate rework costs that were not included in the original cost estimates.

The primary impacts on 5D BIM accuracy include: (1) quantities remaining based on outdated models; (2) model items not being correctly linked to the appropriate cost codes; (3) unit prices failing to reflect the latest quotations or contract values; (4) committed costs not yet incorporated into the model; (5) variation orders and rework costs being excluded from cost calculations; and (6) the estimated final cost failing to account for schedule-related impacts. The 5D BIM literature consistently emphasizes the importance of integrating quantity take-

off, work classification, scheduling, payment management, and cost control within a unified project information environment (Monteiro & Martins, 2013; Smith, 2014; Lu et al., 2016; Pishdad & Onungwa, 2024). Maintaining cost accuracy requires more than updating project geometry alone. Every design modification must also be translated into corresponding changes in cost items, procurement status, and cost forecasts. Therefore, 5D BIM should clearly distinguish between planned costs, committed costs, and actual expenditures.

The Role of 4D BIM and 5D BIM

4D BIM plays a critical role in visualizing the schedule implications of project changes. When design revisions occur or material deliveries are delayed, project teams can immediately identify affected activities, required sequence adjustments, and potential milestone shifts. Such visualization enables engineering, planning, procurement, construction, and commissioning teams to develop a shared understanding of the consequences of project changes.

5D BIM, in contrast, illustrates the financial implications of project changes. Whenever model objects or technical specifications are modified, the project team can update quantity take-offs, calculate cost increases or reductions, and revise project cost forecasts accordingly. Moreover, 5D BIM facilitates comparisons among budgeted costs, committed costs, actual expenditures, and estimated final costs. The combined application of 4D BIM and 5D BIM enables the integration of schedule and cost consequences within a single project information environment. Procurement delays, for example, influence not only the project schedule but also storage costs, acceleration measures, labor expenses, and cash flow. Conversely, cost-related decisions may require modifications to construction methods and activity sequencing.

The effectiveness of BIM depends on several key conditions: (1) the model is updated regularly; (2) information status and revisions are clearly documented; (3) model objects are correctly linked to both project activities and cost items; (4) procurement and field progress data are continuously integrated; and (5) all project stakeholders utilize the same information source. These principles are consistent with the literature that conceptualizes BIM as an integrated information management process rather than merely a three-dimensional modeling software (Succar, 2009; Miettinen & Paavola, 2014; Noardo et al., 2021).

Expert Opinions and Findings from Previous Studies

To strengthen the theoretical foundation of this study, Table 2 summarizes the perspectives and findings reported in 35 peer-reviewed journal articles. The synthesis illustrates the evolution of scholarly understanding regarding the risks associated with overlapping or fast-track project delivery, the accuracy of 4D BIM, the accuracy of 5D BIM, and the role of BIM in integrating schedule and cost information.

Table 2. Expert Opinions and Previous Research Findings on EPCC Phase Overlap, 4D BIM, and 5D BIM (35 Journal Sources)

No.	Expert/Researcher	Main Argument or Findings	Relevance to the Study
1	Peña-Mora & Li (2001)	Fast-track project planning and control should be managed dynamically because design and construction activities continuously influence each other during project execution.	Explains that overlapping phases require more frequent schedule updates and coordination.
2	Peña-Mora & Park (2001)	Fast-tracking can accelerate project delivery but increases uncertainty in activity relationships as well as the	Provides the basis for the relationship between phase overlap, changes in

		likelihood of changes and rework.	work sequences, and schedule accuracy.
3	Garrido Martins et al. (2023)	Construction risk varies according to the degree of overlapping activities; design, coordination, change, and rework risks become major concerns.	Supports the argument that overlap intensity affects the reliability of project information.
4	Wang & Wang (2022)	Procurement risks in EPC projects may propagate to other activities, ultimately affecting project cost and schedule.	Explains the impact of engineering–procurement and procurement–construction overlaps.
5	Azhar (2011)	BIM provides benefits in visualization, coordination, estimation, and scheduling, although its implementation is constrained by interoperability, process, and competency issues.	Confirms that BIM supports project control, but its accuracy depends on implementation quality.
6	Barlish & Sullivan (2012)	The benefits of BIM vary across projects and should be evaluated using measurable performance indicators rather than user perceptions alone.	Supports the use of time and cost accuracy as indicators for evaluating BIM performance.
7	Bryde et al. (2013)	BIM implementation provides significant benefits in cost, time, communication, and project coordination, although these benefits vary across projects.	Reinforces the role of BIM as a coordination tool for time and cost management in EPCC projects.
8	Cao et al. (2015)	BIM effectiveness depends on the depth of implementation, organizational support, team capability, and project process integration.	Explains that software alone is insufficient to maintain BIM accuracy.
9	Succar (2009)	BIM is a combination of technology, processes, and policies involving multiple stakeholders.	Establishes that BIM in EPCC projects should be understood as an information management system.
10	Miettinen & Paavola (2014)	Successful BIM implementation requires changes in work practices and organizational collaboration; benefits do not arise automatically from simply using a model.	Supports the need for cross-phase coordination during overlapping activities.
11	Koo & Fischer (2000)	4D models are effective for understanding construction sequences and identifying scheduling issues that are	Explains the fundamental role of BIM 4D in evaluating the impact of

		difficult to detect using conventional schedules.	overlaps on project schedules.
12	Heesom & Mahdjoubi (2004)	4D CAD supports construction planning and communication, but its implementation depends on standardization, data integration, and modeling processes.	Demonstrates that data connectivity determines the reliability of time-related models.
13	Staub-French & Khanzode (2007)	3D and 4D models improve design–construction coordination when model content, responsibilities, and collaborative processes are clearly defined.	Relevant to engineering–construction overlaps involving frequent design changes.
14	Hartmann et al. (2008)	The use of 3D and 4D models should be aligned with project tasks and decision-making requirements.	Supports the targeted use of BIM 4D for work sequence and constructability analysis.
15	Gledson & Greenwood (2016)	BIM 4D is widely used for visualization, planning, communication, and coordination, although actual adoption varies across organizations.	Explains both the benefits and limitations of BIM 4D implementation in practice.
16	Gledson & Greenwood (2017)	BIM 4D adoption is influenced by perceived benefits, compatibility with work processes, complexity, and organizational capability.	Indicates that BIM performance in overlapping projects depends on organizational readiness.
17	Doukari et al. (2022)	Developing 4D schedules requires an appropriate level of model and schedule detail, clearly defined parameters, assigned responsibilities, and BIM Execution Plan guidelines.	Provides the basis for indicators of object–activity–schedule accuracy.
18	Rehman et al. (2025)	A systematic review identified visualization, communication, scheduling, coordination, and progress monitoring as the primary benefits of BIM 4D.	Summarizes the BIM 4D functions discussed in this study.
19	Turkan et al. (2012)	Integrating 4D schedules with 3D scanning technology enables automated comparisons between planned and actual project conditions.	Supports the use of BIM 4D to measure progress accuracy during overlapping phases.
20	Kim et al. (2013)	Automated progress measurement can be achieved by integrating BIM 4D with three-dimensional field data.	Explains BIM's role in objectively updating construction progress.

21	Zhang & Arditi (2013)	Laser scanning can support automated progress control, but its accuracy depends on data acquisition and processing quality.	Reinforces that reliable field data are essential for maintaining BIM schedule accuracy.
22	Boton (2018)	Virtual reality–based BIM 4D simulations support constructability discussions and shared understanding of construction sequences.	Explains the role of BIM 4D in preventing sequencing conflicts caused by overlapping phases.
23	Monteiro & Martins (2013)	The reliability of BIM-based quantity take-off depends heavily on modeling guidelines and the way model elements are created and classified.	Establishes that BIM 5D accuracy begins with model quality and quantity measurement standards.
24	Smith (2014)	BIM 5D transforms cost management through the integration of models, quantities, and cost information, but requires new standards and competencies.	Explains the role of BIM 5D in updating project costs resulting from overlapping changes.
25	Lu et al. (2016)	Integrating quantities, schedules, lead times, and payment terms within BIM 5D supports cash flow analysis and financial decision-making.	Demonstrates the direct relationship between schedule changes and cost changes.
26	Vigneault et al. (2020)	A systematic review identified various BIM 5D solutions for cost management, although process fragmentation and interoperability issues remain.	Supports the discussion of cost data synchronization risks in EPCC projects.
27	Pishdad & Onungwa (2024)	BIM 5D requires standardized coding and integration of estimating, cost control, progress monitoring, and payment throughout the project lifecycle.	Provides the basis for linking model objects, WBS, and cost codes.
28	Alathamneh et al. (2024)	BIM-based quantity take-off still faces challenges related to software limitations, user skills, modeling standardization, and data loss across platforms.	Explains potential sources of quantity errors in BIM 5D.
29	Hussain et al. (2024)	BIM 5D requires governance frameworks and clearly defined responsibilities to effectively control cost overruns in complex projects.	Reinforces that cost updates and validation require assigned accountability.
30	Khosakitchalert et al. (2020)	The development of BIM-based quantity take-off demonstrates that calculation	Supports quantity accuracy indicators in BIM 5D.

		results depend on model detail and quantity extraction rules.	
31	Laakso & Kiviniemi (2012)	IFC was developed to facilitate BIM information exchange, although its standardization and implementation continue to evolve.	Explains the importance of data exchange formats in maintaining consistency among models, schedules, and cost information.
32	Pauwels et al. (2017)	Semantic web technologies have the potential to improve AEC data integration but require consistent semantic definitions and information structures.	Supports the need for consistent coding and shared data semantics across EPCC processes.
33	Noardo et al. (2021)	Software testing reveals differences in IFC support for geometry, semantics, and functions across different platforms.	Explains the risk of data modification or loss when transferring BIM models between software platforms.
34	Sacks et al. (2010)	Integrating BIM with Lean principles enhances information flow, coordination, process visualization, and waste reduction.	Supports the role of BIM in reducing rework and improving workflow management during overlapping phases.
35	Zhao (2017)	A scientometric review shows that BIM research has rapidly evolved, with adoption, collaboration, interoperability, and project management as major research themes.	Demonstrates that organizational factors and data integration are essential aspects of BIM research.

Conclusion

Overlapping phases in EPCC projects are implemented to accelerate project delivery by allowing multiple project phases to proceed simultaneously. However, this overlap may result in changes to design, specifications, materials, work sequences, schedules, and costs after subsequent phases have already commenced. The impact of overlapping phases on 4D BIM is reflected in changes to object–activity relationships, construction sequences, activity dependencies, durations, project progress, and completion schedules. Its impact on 5D BIM is evident through changes in quantities, unit prices, committed costs, rework expenses, scope modifications, and estimated final costs. The accuracy of both 4D BIM and 5D BIM decreases when these project changes are not incorporated into the model in a timely manner.

4D BIM assists project teams in visualizing the schedule implications of project changes, while 5D BIM supports the evaluation of their cost consequences. The integration of these two BIM dimensions enables EPCC teams to better understand the interrelationships among engineering decisions, procurement activities, construction execution, and commissioning. Although BIM cannot eliminate the risks associated with overlapping project phases, it provides a platform for identifying, visualizing, and managing those risks more effectively. The accuracy of BIM can be maintained through regular model updates, clear revision status management, proper integration of model objects with schedules and cost information, incorporation of procurement status and site progress data, and continuous coordination across all project phases.

Limitations and Suggestions

As this study is based on a literature review, it does not quantitatively measure the statistical impact of overlapping phases. Furthermore, the reviewed articles differ in terms of project types, research indicators, and methodological approaches. Therefore, future research is recommended to utilize data from actual EPCC projects to quantitatively evaluate the degree of phase overlap, the number of project changes, model update frequency, schedule forecast errors, quantity variations, and deviations in estimated final costs. Case studies involving industrial, energy, or infrastructure projects are also needed to empirically validate the relationships discussed in this study.

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