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Extended-Dimension BIM-5D Applications in Engineering General Contracting Mode

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Abstract. This study positions Building Information Modeling (BIM) - 5 Dimensional (5D), a BIM extension that combines a 3D model with time and cost dimensions, as the central digital support for an integrated management system across design, procurement, and construction in the face of ongoing cost escalation, schedule slippage, and phase discontinuities in Engineering-Procurement-Construction (EPC) projects. Three analytical axes are used in the discussion: (i) multi-actor and cross-disciplinary collaboration; (ii) execution that is focused on efficiency and precision; and (iii) intelligent and green construction. Research demonstrates that BIM-5D reduces design-site discrepancies, rework, and change orders by connecting design and construction through model-based review and virtual construction. EPC contractors may run a closed loop between plan and execution thanks to the framework's ability to tie component-level quantity take-offs to budgeting, synchronize them with 4D schedule visualization, and provide deviation notifications. Simulated energy use at the same time. Environmental monitoring and Internet of Things (IoT) field data facilitate scenario-based resource allocation and reduce material and carbon waste. All things considered, EPC projects that use BIM-5D can accelerate the transition to green and intelligent delivery by moving toward a data-driven, whole-process governance paradigm where quality, time, and cost are jointly managed and auditable.

Keywords: Building information modeling; Engineering-procurement-construction projects; Green and intelligent construction.

1. Introduction

In the midst of the construction industry's continuous digital transformation, increasing project complexity, the diversity of owner and regulatory requirements, increased technical risk, and environmental uncertainty have resulted in long-lasting, system-level pressures that show up as schedule slippages and cost overruns. Importantly, discontinuous information flows and sluggish, poorly coordinated decisions throughout the design, procurement, construction, and close-out continuum are the root causes of these problems rather than just being the result of local inefficiencies on site. Design modifications cause rework and extensive rescheduling as they trickle down to procurement and construction. Regular changes to sourcing requirements also lead to inconsistencies in logistics and material preparation, which raises the proportion of change-related expenses in overall spending and increase schedule risk [1]. The paradox of system-level goal alignment amid fragmented local constraints is perpetuated by the design, procurement, and construction functions continuing to operate in silos despite the fact that Engineering-Procurement-Construction (EPC) delivery aims to reduce cross-phase frictions through organizational integration. This is because there is no unified data backbone or process-level metrics. As a result, significant cost overruns and serious schedule slippages continue to occur often, impairing delivery performance and highlighting the pressing need for focused technology solutions [2]. BIM-5 Dimensional (5D), an extension of Building Information Modeling (BIM) that combines 3D geometry with time and cost, provides a technical pathway of "(1) Semantic unification of the model(2) Schedule–cost coupling (3) Closed-loop deviation governance" to address the aforementioned issues. Using the work breakdown structure (WBS) as the primary index, it maps components, bills of quantities (BoQs), resources, and contractual milestones to a unified semantic space, thereby establishing a dynamic control framework that "models once and reuses across the entire lifecycle." In the design stage, it mitigates downstream changes by front-loading 3 Dimensional (3D) design reviews and multidisciplinary clash detection [3]. In the preparation and procurement stages, it verifies supply and purchasing plans against quantity take-offs and resource curves. During construction, it links 4D schedules with costing and measurement, and constrains the cash-flow S-curve and earned value by the critical path and quality gates, thereby enabling visualization of plan-actual deviations and rapid corrective action [4]. China's Ministry of Housing and Urban-Rural Development (MOHURD) proposes in the "14th Five-Year Plan for the Development of the Construction Industry" to accelerate the integrated application of Building Information Modeling (BIM) across the full project lifecycle, and emphasizes advancing whole-process BIM deployment in Engineering-Procurement-Construction (EPC) projects to foster deep integration between technology and management, and between design and construction. Aligned with this policy direction, evidence across diverse project types demonstrates the scenario-specific value of BIM-5D. In large mixed-use complexes, BIM's visualization and simulation capabilities strengthen design-construction interfaces and commercial integration, thereby enhancing standardization and decision reliability; in whole-process management of building projects, linking contracts and cost budgets with 4D schedules as well as resource and cash-flow curves-together with visualized plan-actual variance and dynamic correction-improves logistics organization and site utilization under safety constraints [1]. This paper examines how BIM-5D platforms catalyze the adoption of intelligent construction technologies, address persistent challenges in conventional EPC delivery, and explore their broader prospects for application in future construction projects.

2. Optimising Collaborative Work in EPC Projects with BIM-5D

2.1. Resolving Design-construction Interface Issues

In EPC delivery, ineffective interfaces between design and construction often impede collaboration and preclude the maximization of overall project value. In conventional projects, inadequate design detailing or a misalignment between design intent and site realities precipitates rework and change orders (variations) during construction, thereby prolonging the schedule and inflating costs [2]. BIM-5D integrates multidimensional information across the project lifecycle to establish a digital collaboration framework that enables a seamless design-construction interface. Leveraging BIM-5D's model-based visualization environment, design teams can perform high-fidelity clash detection and scheme refinement at the preconstruction stage, so that typical coordination conflicts-most prominently MEP routing, elevation overlaps, and space occupation in congested zones-are exposed and neutralized before they propagate to site execution. In an EPC research-facility project, a single BIM-5D clash-detection run surfaced 15 pipeline conflicts and directly informed a round of design reconfiguration, which in turn eliminated follow-on site rework and compressed the construction schedule by roughly seven days. Similarly, in a residential scheme, the rework ratio decreased from 3.7% to 0.9% when drawing errors, omissions, inter-trade conflicts, and detail deficiencies were removed early following BIM-5D implementation [5]. When combined, these findings imply that the issues that BIM-5D is addressing-pipeline interference, drawing-level incoherence, and cross-discipline misalignment-are common, recurrent problems at the design-construction interface of EPC projects rather than isolated occurrences. Through upstream recalibrating of the detection-and-correction cycle and connecting design deliverables with construction plans within a single digital platform, BIM-5D minimizes the interdisciplinary coordination frictions associated with traditional workflows. This reduces the possibility of rework, delays in the timeline, and cost overruns that arise from inadequate interface governance. The coherence, accuracy, and dependability of integrated design-construction delivery in EPC projects are also significantly improved by the collaborative iteration of design changes and construction techniques within the model in real time. This guarantees temporal and technical alignment between design intent and constructability.

2.2. Synchronised Schedule-cost Management

BIM-5D augments the 3D information model with time (4D) and cost (5D), enabling synchronized management of the construction schedule and cost control. This integrated approach remedies the siloed, lagged information flows typical of conventional schedule management and cost control, thereby making project governance more timely and forward-looking [6]. Via the BIM-5D platform, project teams link the schedule to model elements, quantity take-offs, and budget line items; track physical progress and percent complete (earned value) in real time; and flag deviations for prompt replanning. In parallel, contractual budgets and actual cost records are dynamically associated within BIM-5D, allowing managers to disaggregate and monitor phase-specific expenditures over time and achieve fine-grained, integrated schedule-cost control. For example, in the Zengjiapo residential-commercial EPC project, BIM-5D's schedule control and quantity-tracking functions reduced actual expenditures by RMB 3.25 million relative to the initial budget and lowered the material waste rate by 2.3 percentage points. BIM-5D's real-time schedule monitoring and risk-alert mechanisms further shortened the planned duration from 820 to 783 days-an early completion by 37 days-thereby avoiding delay-related costs [5]. In contrast, the project's schedule and cost functions would have probably remained isolated with a delayed information flow if BIM-5D had not been implemented, making it challenging to identify and promptly address progress deviations and cost overruns.[2] The project team would be unable to closely couple and modify the schedule to actual completions and expenditures without the real-time monitoring and early-warning features of BIM-5D. They would also be unable to watch production progress and cash outflows dynamically. Accordingly, BIM-5D gives EPC projects more planning accuracy and cost-management efficiency by closely integrating schedule planning with cost control and offering real-time feedback on production and cash-flow conditions.

2.3. Information Sharing and Real-time Updates

Throughout all EPC stages, the BIM-5D platform sets up a digital workspace for the entire project, facilitating simultaneous information sharing and version-consistent updates. Interdepartmental data transfer is usually asymmetrical, fragmented, and delayed under traditional, document-driven management. This leads to communication noise and decision latency, which eventually show up as budget drift and coordination issues. The most recent models, schedules, RFIs, and site modifications can be queried and maintained from a cloud-hosted, single-source-of-truth database once BIM-5D is deployed. This enables update cycles to be shortened from weekly collation to daily-or, where field connectivity permits, near-real-time-refresh. In one recorded instance, cloud-based collaboration on BIM-5D significantly reduced latency-induced miscommunication and increased cross-functional coordination efficiency by cutting the information-refresh interval from seven days to about 1.2 days [5]. Because the shared platform allows all parties to push and pull drawings, method statements, and change information as needed, interdepartmental retrieval times are greatly shortened. Glodon BIM-5D software can be integrated with three terminals: the PC terminal, the external webpage end, and the mobile terminal. The three terminals are fully connected and process the data collectively.[10] A crucial technical tool for addressing the persistent coordination delays inherent in traditional project delivery, this unified, real-time data backbone successfully eliminates information blind spots in EPC collaboration. With BIM-5D technology, as long as there is a network, the quality problems in the project can be inquired and marked at any time, and the rectification can be carried out timely; project managers can make effective analyses and decisions in the face of complex construction project management, specialist teams coordinate more smoothly, and risks and management biases arising from outdated information are curtailed-collectively enhancing the efficiency and quality of collaboration in EPC projects [7,9].

3. Enhancing Accuracy and Efficiency in EPC Projects with BIM-5D

3.1. Accurate Quantity Take-off and Budget Management

BIM-5D shifts quantity and cost accounting from experience- and ledger-based practices to model- and data-driven ones, fundamentally improving the accuracy and traceability of budgeting and payment management. Compared with traditional approaches centered on experiential judgement and historical ledgers, BIM-5D overlays cost and schedule dimensions onto the 3D model and, through dynamic construction simulation and process visualization, markedly increases managerial efficiency and decision accuracy [8]. In implementation, BIM extends 4D scheduling into a 5D cost model, from which cash flow and resource curves are derived, enabling dynamic comparisons of planned versus actual cost and planned versus actual resources [1]. These practices have proved feasible in complex works such as large commercial complexes and airports: in airport settings, parallel management of the contract bill of quantities (BoQ), the model-based BoQ, and the non-model BoQ-together with element-level measurement and workflow-based approvals-effects an institutional shift from "subjective declarations" to "objective measurement" [4]. Taken together, the evidence indicates that BIM-5D, using the model as the carrier and leveraging BoQs and cash-flow curves, establishes a standardized, auditable budgeting and payment system that improves the accuracy and transparency of cost management.

3.2. Visualised Management of Construction Schedules

BIM-5D upgrades schedule management from static, plan-based control to dynamic governance with a deeply coupled "model-schedule" relationship. Specifically, linking the master schedule to the 3D model yields a 4D schedule model that, in a single view, presents process logic, work-section delineation, and on-site resource allocation; during execution, actual start/finish times, earned value, and quality data are continuously backfilled, enabling intuitive plan-actual comparisons and variance tracking [4]. At the implementation level, BIM-5D follows a "data import-model federation-segment delineation-schedule linkage-construction simulation" workflow, binding element-level quantities to work activities in real time; this surface lagging tasks visually and supports rapid re-baselining and resource reallocation [8]. For schedule management, the contractor of the Shenzhen Evergrande Centre adopted a "BIM + Internet" approach, using BIM-5D collaboration platforms such as Yunzhu for site management. A visual, parametric 3D construction model was dynamically linked to the Gantt schedule, enabling intuitive simulation and comparison within the model and compressing the critical-path duration by 18%. For quality management, the Shenzhen Haiyi Village project employed a BIM-5D quality-inspection system, reducing corrective response time from 48 hours to 2 hours. Thus, when scope changes or delays occur, the platform can automatically reconstruct downstream plans and daily worklists based on actual progress, while simultaneously recalculating the associated quantities and costs, thereby reducing human error in secondary planning and improving the efficiency of corrective actions [5].

3.3. Real-time Monitoring and Early Warning of Construction Risks

BIM-5D provides the data backbone for real-time monitoring and forward-looking early warning of construction risks and, via a "BIM-5D + IoT/AI" approach, enables multi-source data acquisition, recognition, and coordinated response. As an integration platform, BIM-5D interconnects the model, equipment, energy use, and safety-monitoring systems, supporting statistical analysis of equipment states and energy consumption alongside fault diagnosis. This replaces portions of manual inspection and reduces labor costs. Through digital-twin representations, it localizes risk points to the element and activity levels and supports quantitative, preventive decision-making [7]. Studies further indicate that a lifecycle-oriented "BIM-5D + AI/IoT/big-data" architecture links resource plans, cash-flow plans, and quantity data across scheme, design, and construction phases, enabling real-time information sharing and dynamic simulation. In doing so, BIM5D technology can focus on the key points and difficulties in the project, preview them in advance, reduce the problems that may appear in the process, and prepare measures as soon as possible to solve the problems and it shifts risk identification upstream into integrated design-construction and markedly improves risk pre-emption and response times [7].

4. Driving EPC Projects Toward Green and Intelligent Delivery with BIM-5D

4.1. Energy-efficiency Optimisation and Operation and Maintenance cost Reduction

As a cross-phase data backbone, BIM-5D couples the 3D information model with time and cost dimensions and, on a project-level platform, supports end-to-end management across design, construction, and operations. This embeds energy-saving targets within process control. Through dynamic simulation and unified management of construction processes, BIM-5D markedly improves managerial efficiency and accuracy, providing verifiable data lineages and procedural evidence for green objectives [8]. For operations and maintenance, BIM-5D can interface with energy management and building automation systems, enabling model-based energy accounting, strategy formulation, and equipment diagnostics. This data-closed loop supports energy optimization and operation and maintenance cost reduction for the building envelope and MEP systems, mitigating hidden energy waste stemming from suboptimal design or operation. In addition, BIM-5D + VR visualization of design options and construction sequences identifies and optimizes energy-intensive or hard-to-access operations before mobilization, lowering rework rates and material redundancy and further consolidating green-construction outcomes [9].

4.2. Application of Intelligent Construction Equipment

During construction, the BIM-5D-enabled intelligent collaboration platform maps work packages and resource constraints into a unified semantic space, enabling fine-grained control of automated operations and plant allocation, while process visualization safeguards quality and efficiency. In practice, BIM-5D links the construction model, cost documentation, schedule, and site-layout model to create a dynamic, whole-of-construction management and simulation environment. This supports procedure optimization, data capture and refinement, and improves labor-materials-plant matching efficiency, and shortens the schedule. To ensure end-to-end coordination, the platform provides interconnected mobile/PC/web mechanisms for data capture and backhaul; site data are uploaded in real time and synchronized on the platform, significantly shortening information chains, reducing manual aggregation errors, and enhancing the timeliness of multi-party coordination [8].

4.3. Environmental Monitoring and Resource Optimisation

When integrated with the Internet of Things (IoT), BIM-5D enables real-time acquisition of on-site environmental parameters-such as noise, dust, and temperature-humidity-as well as equipment status and fleet-management data, and backfills these into the model. This renders managed objects visible, measurable, and traceable in space and time; supports threshold-based classification and zonal governance; and raises levels of environmental compliance and site safety [9]. On the resource side, BIM-5D' cumulative resource curves and plan-actual comparisons can show, over time, cash-flow differences and the gaps between planned and actual labor, materials, and equipment. By allowing resources to be reallocated across tasks, supporting rolling, real-time adjustments, and optimizing the rhythm of procurement, these functions help cut idle stock and material waste, while also reducing the risk of extra carbon emissions and chain-style schedule delays caused by poor resource allocation. In addition, by using real-time as-built data, the platform can embed warning mechanisms and corrective actions into closed-loop systems in the model and schedule interfaces, run simulation-based checks, and react to parts of the project that are not performing well. This makes sure that resource-optimization measures and green-construction goals can really be carried out at the day-to-day operation level [8].

5. Conclusion

In conclusion, this paper focuses on the structural barriers to the EPC delivery paradigm and explains how BIM-5D can act as a digital facilitator for truly integrated, lifecycle-focused project management. The findings reveal that implementing BIM-5D establishes a cross-phase, multi-stakeholder collaboration platform, breaks down information silos between design, procurement, and construction stages, and allows for real-time sharing of critical design, schedule, and cost data. By leveraging this digital infrastructure to achieve synchronized control over schedule and cost, improve transparency, and minimize unplanned change orders caused by information asymmetry, project stakeholders can significantly reduce project duration, effectively control costs, and improve quality. At the same time, BIM-5D promotes fine-grained project governance by combining cost data with component-level quantity take-offs, allowing for dynamic and quantitative monitoring throughout the project. Managers may maintain a thorough picture of the state of their projects by utilizing visual aids and early warning systems, ensuring that schedule plans and cost budgets are well linked, and identifying potential delays and other dangers early on. Furthermore, it discover that BIM-5D has a positive impact on green construction and the industry's digital-intelligent shift: BIM models support environmental impact analysis and energy-use simulation during design, allowing for scheme optimization that reduces operational energy demand. BIM-5D makes it easy to assess the environmental impact of various materials when selecting and using them, promoting sustainable project development and resource efficiency. BIM-5D improves organizational coordination, site conditions, and resource allocation during construction, resulting in increased efficiency and decreased consumption for the project.

Based on the preceding facts, it make the following prognosis and recommendations: To fully achieve the integrated control over time, cost, and quality that BIM-5D provides, EPC project managers should actively extend its use, incorporate it into standardized management procedures, and improve teamwork and data governance. Simultaneously, as new technologies like as digital twins, big data, and artificial intelligence are integrated into BIM-5D, it is predicted to evolve from a visualization-plus-tallying supplementary tool to an intelligent hub for engineering management. As a result of this co-evolution, future BIM-5D systems will transform into engines for cognitive analytics and optimization, providing autonomous decision support and process-optimization approaches for EPC projects rather than static information repositories.

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