Schedule-Driven Lightweight 4D Simulation for the Setup Phase: Enabling Practitioner-Led Construction Planning

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Abstract –

In high-context construction cultures like Japan, the Setup phase—comprising *nemawashi* (consensus-building) and *dandori* (operational preparation)—is critical for reliable execution. While BIM models are increasingly available, site engineers often lack the modelling expertise to evaluate them independently. This reliance on specialists creates bottlenecks, forcing planning back to manual quantity take-offs and 2D drawing-based scheduling. Adopting a Design Science Research (DSR) approach, this study proposes a "schedule-driven lightweight 4D simulation workflow" to restore practitioner agency.

The workflow enables engineers to author schedules using a cloud-based tool, export data as CSV, and automatically link it to simplified Revit Box mass elements via native Key Schedules. Crucially, these Boxes act as spatial filters, automatically calculating quantities for specific structural components—including girders, beams, columns, sub-columns, and dampers—while utilizing Revit Assemblies to accurately count lifting units. The system simultaneously generates color-coded, flipbook-style 4D visualizations without specialist intervention.

A pilot workshop with five practitioners from a Tier-1 general contractor validated the approach. Baseline surveys revealed that 80% of participants previously relied on manual quantity take-offs. Following system use, participants rated its effectiveness for quantity verification and stakeholder communication at 4.40/5.00. A small comparison with conventional practice suggested that equivalent quantity verification and 4D output generation could be completed in 15–20 minutes, with minor revisions in 2–5 minutes. These findings suggest that lowering technical barriers to BIM access through lightweight Process Information Models (PIM) can enable practitioner-led construction planning and help bridge the gap between digital planning intent and on-site execution.

Keywords –

BIM accessibility; 4D simulation; Practitioner agency; Construction planning; Schedule-driven planning; Process Information Model (PIM)

1 Introduction

Production Planning and Control (PP&C) is a central yet challenging component of construction management due to the socio-technical nature of construction projects. To address uncertainty and variability in production, Lean Construction has advanced the Last Planner System (LPS), which emphasizes collaborative planning and reliable workflow as mechanisms for stabilizing execution [1,2].

Despite these advances, PP&C discussions have often been framed primarily around "planning" and "control," while the transitional work that connects planning decisions to executable site actions remains under-specified. The importance of managing handoffs between specialists to achieve project goals has been highlighted [3]. However, intermediate coordination activities frequently lack formal structure, and assigning adequate staff to such work is known to be fraught with pitfalls [4]. In practice, this "in-between" work relies heavily on tacit knowledge and informal coordination, making it difficult to standardize processes or support them systematically.

To better conceptualize this gap, the Four-fold Framework for Process Information Management extends PP&C into four phases: Planning, Setup, Execution, and Control [5].

At the same time, BIM models from design and fabrication stages are increasingly available in contemporary projects and contain rich geometric and quantitative information that could support Setup-phase coordination. However, practical adoption remains limited when site engineers cannot directly utilize these models for production planning. A major barrier is the heavy reliance on BIM specialists to generate or modify BIM-based 4D outputs, which typically requires advanced modelling skills and familiarity with specialized software environments. Prior studies have reported that such skill, workflow, and organizational barriers hinder both BIM implementation and the adoption of 4D modelling in practice [6,7]. As a result, iteration cycles during the Setup phase slow down, and planning frequently falls back to manual quantity take-offs and 2D-based coordination.

To address this problem, this study focuses on the accessibility of BIM-based planning during the Setup phase. Specifically, this paper proposes a schedule-driven lightweight 4D simulation workflow that enables site engineers without advanced BIM expertise to verify *dandori* and facilitate *nemawashi* by linking schedule information to existing models and generating time-based visual evidence for coordination. By reframing the difficulty of 4D simulation as an accessibility problem rather than a purely technical one, this research seeks to restore practitioner agency and support field-driven production planning.

2 Theoretical Framework: The Setup Phase and Process Information

2.1 The Four-fold Framework for PP&C

This study adopts the "Four-fold Framework for Process Information Management" proposed by Shigaki et al. [5], which extends the PP&C cycle into four distinct phases: Planning, Setup, Execution, and Control.

Within this framework, the Setup phase plays a pivotal role as the connective layer between abstract planning and value-adding execution on site. Rather than being a passive preparatory step, Setup is understood as an active phase in which planning assumptions are translated, negotiated, and validated before execution begins. The effectiveness of this phase directly influences workflow continuity, coordination efficiency, and the reduction of downstream disruptions. Table 1 summarizes the four phases and typical process information exchanged across them.

Table 1. Four phases and typical process information in PP&C (adapted from [5])

Phase	Representative information	Typical outputs
Planning	targets, constraints, work packages	plans (master/phase/lookahead)
Setup	zones, quantities, prerequisites, handoffs	nemawashi/dandori decisions
Execution	progress, actuals, issues	daily/weekly records
Control	variances, corrective actions	re-plans, improvements

2.2 Defining the Setup Phase: *Nemawashi* and *Dandori*

In high-context construction cultures such as Japan, the Setup phase is characterized by two interrelated practices: *nemawashi* and dandori. *Nemawashi* refers to the informal yet essential process of consensus-building among stakeholders, through which social, organizational, and contractual constraints are addressed before physical work begins. *Dandori*, in contrast, focuses on the technical and operational preparation required to realize planned activities. It involves verifying work-zone quantities, sequencing tasks, allocating resources, and confirming logistical feasibility.

Despite the availability of 3D BIM models in contemporary projects, both *nemawashi* and *dandori* often rely on manual, drawing-based methods. This disconnect occurs because BIM models exist but are not directly accessible to site engineers for independent evaluation. In current practice, engineers cannot independently verify quantities or test alternative construction sequences; instead, they depend on BIM specialists for iterative support. When digital tools fail to support independent exploration during this phase, the Setup phase becomes a bottleneck, disrupting workflow continuity and limiting the potential benefits of BIM-based planning.

Figure 1 illustrates the conventional Setup-phase workflow targeted by the proposed system. In existing practice, site engineers rely on manual quantity take-off for *dandori*, while 4D visualization for *nemawashi* requires manual task–element linking in tools such as Navisworks and Synchro. These workflows impose hidden coordination costs and often depend on BIM specialists.

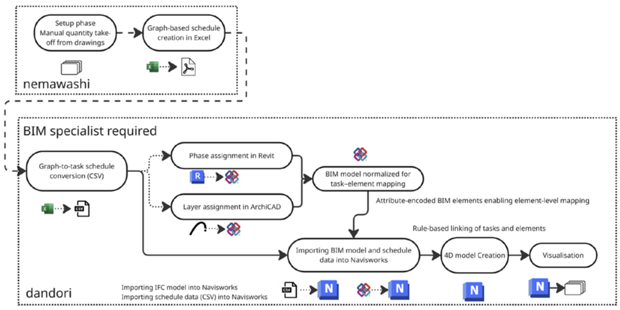

Figure 1. Conventional Setup-phase workflow showing manual quantity take-off and specialist-dependent 4D linking.

2.3 Process Information Model (PIM)

To rationalize the Setup phase, this study employs the concept of a Process Information Model (PIM) [12]. Unlike product-oriented BIM models that focus on "what" is being built, a PIM emphasizes "how" and "when" construction activities occur by associating dynamic process attributes with geometric elements. Typical PIM attributes include work zones, task identifiers, scheduling parameters, quantities, and labor requirements. By embedding such information into the model, PIM enables evaluation of spatial and temporal feasibility rather than purely geometric correctness.

In this research, a "lightweight" PIM is defined not merely by file size, but by its accessibility in three dimensions: (1) Cognitive: utilizing familiar planning concepts (e.g., zones) rather than complex BIM logic; (2) Technical: relying on standard software features (e.g., native parameter mapping such as Key Schedules) to avoid custom development; and (3) Operational: enabling rapid iteration by non-specialists. This contrasts with heavyweight PIM approaches that demand full BIM authoring capabilities and specialized knowledge.

The lightweight PIM is implemented by mapping schedule information to simplified volumetric elements (e.g., mass boxes). A scheduling tool is used as the planning interface, while mass elements are used to avoid complex geometric modeling, thereby maintaining the "lightweight" principle. This design enables the PIM to function as a bridge between scheduling logic and spatial validation, allowing site engineers to work within familiar concepts without specialist intermediaries. The lightweight PIM supports two key evaluations during Setup: (1) Spatial feasibility, confirming work-zone quantities and checking consistency for operational preparation (supporting *dandori*); and (2) Temporal feasibility, visualising sequences and communicating construction logic to stakeholders (supporting *nemawashi*).

3 Methodology（Design Science Research）

This study adopts the Design Science Research (DSR) approach presented by Hevner et al. [8] to address the heavy reliance on BIM specialists for generating 4D simulations during the Setup phase (*nemawashi* and *dandori*). Following the "build–evaluate" cycle described by March and Smith [9], we designed a practical artifact and evaluated it in a real project setting. The goal is to enable site engineers to verify quantities and explore planning scenarios independently, without requiring advanced modeling skills.

The artifact developed in this study is a schedule-driven lightweight 4D workflow. This workflow serves as an instantiation of the lightweight Process Information Model (PIM) interface described by Shigaki et al. [5]. Specifically, the system maps schedule data from GaNett (CSV) to simple Revit mass elements (Box) using standard Key Schedules and Dynamo Player automation. To ensure accessibility for non-specialists, we designed the workflow to be "lightweight" in three dimensions: (1) Cognitive: using familiar planning concepts (e.g., zones) instead of complex BIM logic; (2) Technical: using Dynamo Player as an execution interface to minimize setup and avoid custom plugin development for end users; and (3) Operational: enabling rapid iteration cycles to support dynamic site discussions.

To validate the utility and accessibility of the artifact, we conducted a pilot workshop with practitioners possessing diverse levels of BIM experience. Data were collected via post-workshop questionnaires (Likert-scale items and open-ended comments). In particular, the evaluation focused on accessibility, perceived usefulness, and practitioner agency (i.e., the ability to explore scenarios without specialist mediation) during Setup-phase coordination. We analyzed the results following DSR evaluation guidance recommended by Hevner et al. [8] and Peffers et al. [10] to examine whether the workflow effectively supports *nemawashi* and *dandori* activities.

4 Proposed System

4.1 System Overview and Design Rationale

The proposed system is a schedule-driven lightweight 4D simulation workflow designed to support Setup-phase coordination by site engineers without advanced BIM authoring expertise. In contrast to conventional 4D workflows that require detailed model authoring and specialist intervention, this system treats the BIM model as a verification and visualisation medium rather than the primary planning interface. The core design principle is to align the system with existing planning practices while minimizing cognitive, technical, and operational barriers.

The system focuses on two critical structural processes—steel erection and concrete placement—as representative high-impact activities where site engineers must verify quantities and communicate sequences under tight coordination constraints. By targeting these activities, the workflow supports simultaneous quantity verification and sequence visualisation, consistent with the lightweight Process Information Model (PIM) concept described in Section 2.3. Figure 2 illustrates the overall system architecture, highlighting the data flow from the scheduling tool to the 4D visualisation output.

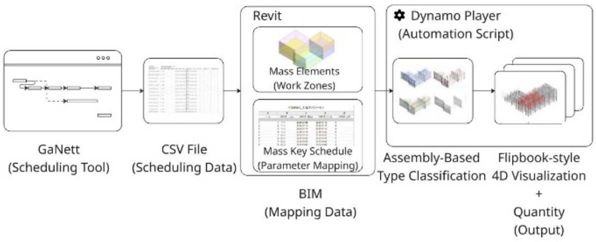

Figure 2. Overview of the schedule-driven lightweight 4D workflow (GaNett → CSV → Revit Key Schedule + Dynamo Player → flipbook output).

In contrast to the conventional 4D workflow illustrated in Figure 1 (Section 2), where manual task-element linking and specialist intervention are required, the proposed system eliminates these dependencies through spatial containment logic. This comparison highlights the reduction in cognitive and operational barriers achieved by the lightweight approach.

4.2 Schedule-Driven Workflow

The workflow begins with schedule authoring using an in-house cloud-based planning tool (GaNett) tailored for Japanese graph-based planning practices [11]. Site engineers define work packages using familiar concepts such as work zones, task identifiers, durations, and quantities. The schedule is then exported in CSV format, serving as the primary source of process information.

The Dynamo script includes a Python node that cleans and standardizes the exported CSV before Key Schedule mapping. Because this node is the sole adapter between the scheduling tool's export format and the Dynamo script's input schema, only this single node needs modification to support alternative tools (e.g., MS Project, Primavera P6); all downstream automation remains unchanged.

In the BIM environment, an existing structural model from design or fabrication stages is reused without modification. Instead of authoring detailed construction elements, site engineers define Box mass elements to represent work zones (*koku*). These volumetric elements act as lightweight spatial containers and are used as spatial filters to query structural and concrete elements located within their boundaries (e.g., girders, columns, braces, slabs, and walls). As shown in Figure 3, schedule attributes from the CSV file are linked to the Box mass elements using Revit's native Key Schedule functionality. This key–value mapping strategy associates each work zone with its corresponding task information, enabling consistent parameter population without custom plugin development.

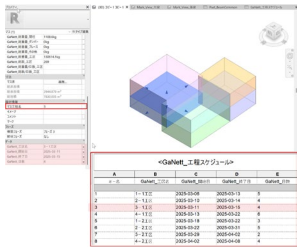

Figure 3. Mapping schedule attributes to Box mass zones using Revit Key Schedules.

4.3 Automation and Execution

A pre-configured Dynamo Player script executes the core automation steps. The script reads the schedule CSV file, matches zone identifiers, and generates two key outputs—quantities and 4D visualisations—tailored to the targeted processes:

1. Automated quantity verification. The system applies calculation rules based on the material type found within the Box zones.

- Steel erection: The workflow calculates total weight and piece count, categorized by specific component types including Columns, Beams, Girders, Sub-columns, and Dampers. Piece counts are derived from Revit Assemblies, allowing users to pre-group multiple elements (e.g., a column and its brackets) into a single lifting unit. This supports detailed logistics planning for cranes and trucks (Figure 4).
- Concrete placement: The workflow calculates volume and area using geometric intersection between Box masses and concrete elements. This enables zone-based quantity take-off for slabs or walls split by zone boundaries (e.g., construction joints) without physically splitting BIM elements.

2. Flipbook-style 4D visualisation. Based on schedule timing information for steel and concrete tasks, the system generates time-indexed 4D outputs. To ensure intuitive comprehension, a simple color-coding scheme is applied to indicate three distinct states: Not Started, Under Construction, and Completed. These outputs are exported as sequential images, forming a flipbook-style representation of the construction process (Figure 5). This format was selected to support rapid review, comparison, and communication during Setup-phase discussions, prioritizing speed and clarity over high-fidelity animation.

Manual operations are limited to three actions: exporting the schedule CSV, defining Box mass zones, and executing the Dynamo Player script. All data linking, quantity aggregation, and visualisation generation are automated, maintaining the "lightweight" principle for end users.

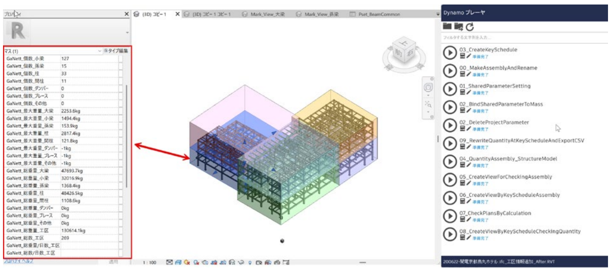

Figure 4. Automated Quantity Aggregation using Dynamo Player. The Dynamo Player (right) executes the spatial filtering logic, calculating quantities for each Mass element (centre). The system automatically aggregates piece counts and weights for specific element types—such as girders, beams, and columns—and populates the results directly into the Mass element's properties (left) for verification (*dandori*).

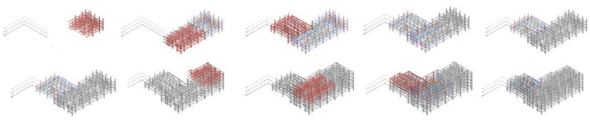

Figure 5. Example flipbook-style (*parapara manga*) 4D output for Setup-phase review (selected time steps).

4.4 Supporting Setup-Phase Activities

The proposed system directly supports the two core activities of the Setup phase defined in Section 2.2:

- Supporting *dandori* (operational preparation): Zone-based quantity aggregation enables site engineers to verify consistency between planned quantities and spatial work zones. By visualising quantities and sequences together, potential issues such as missing scope, incorrect zone definitions, or unrealistic sequencing can be identified early.
- Supporting *nemawashi* (consensus-building): The time-sequenced image outputs provide intuitive visual evidence that can be shared with stakeholders who do not use BIM tools. This facilitates discussion of construction logic, spatial constraints, and sequencing decisions without requiring specialist mediation. Through rapid re-execution of the workflow, practitioners can iteratively adjust schedules, regenerate visual outputs, and compare alternatives within short timeframes. This capability enables exploratory "what-if" discussions that are essential during the Setup phase.

4.5 Summary

By combining schedule-driven planning, lightweight spatial representation, and automated parameter mapping, the proposed system provides a practical implementation of a lightweight PIM for Setup-phase coordination. The system lowers barriers to BIM-based 4D reasoning and enables practitioner-led verification and communication, directly addressing the structural dependency on BIM specialists identified in Sections 1 and 2.

5 Evaluation and Results

5.1 Evaluation Design

The proposed system was evaluated through a pilot workshop conducted with a Tier-1 Japanese general contractor. Following the Design Science Research (DSR) approach described in Section 3, the evaluation assessed the perceived utility and accessibility of the artifact in an authentic Setup-phase planning context, rather than statistical generalization.

Five practitioners participated in the workshop, including site engineers and planning staff who are typically involved in *nemawashi* and *dandori* activities. Participants had diverse levels of experience with Revit and BIM-based workflows, ranging from limited exposure to routine use. No prior experience with BIM authoring or 4D simulation was required.

The evaluation focused on three criteria derived from the research objectives and theoretical framework: (1)**Accessibility:** whether practitioners perceived the workflow as usable without specialist support; (2) **Perceived usefulness:** whether the workflow supported quantity verification (*dandori*) and stakeholder communication (*nemawashi*) during the Setup phase; and (3) **Practitioner agency:** whether practitioners felt able to independently explore construction scenarios.

5.2 Data Collection

Data were collected using a post-workshop questionnaire consisting of Likert-scale items (five-point scale: 1 = strongly disagree, 5 = strongly agree) and open-ended questions. In addition, a short baseline questionnaire was administered prior to system use to capture participants' perceptions of current Setup-phase practices and challenges.

The questionnaire items addressed: (A) current challenges in quantity understanding and communication, (B) perceived improvements in stakeholder communication, (C) perceived improvements in evidence-based quantity takeoff, (D) perceived ability to independently explore scenarios, and (E) overall usability and intention to adopt the workflow.

5.3 Baseline Perceptions of Current Practice

The baseline questionnaire indicated that manual, drawing-based work remains a major perceived bottleneck in Setup-phase planning. Specifically, 80% of participants reported that zone-based quantity understanding still relies on manual take-offs, and 80% reported difficulty explaining construction logic to stakeholders using static drawings alone.

These responses suggest that, even when BIM models are available, critical Setup-phase tasks related to *dandori* (quantity verification) and *nemawashi* (coordination) are widely perceived as difficult to support effectively using existing 2D-based practices.

5.4 Results After System Use (Quantitative)

After using the proposed schedule-driven lightweight 4D workflow, participants evaluated its contribution to Setup-phase activities. The mean rating for improving stakeholder communication (Question B) was 4.40/5.00, and the mean rating for enabling evidence-based quantity take-offs (Question C) was also 4.40/5.00. Participants rated the ease of operation of the workflow at 4.00/5.00, indicating that the system was perceived as accessible for practitioners without advanced BIM expertise. The intention to use the workflow in practice was rated positively (4.00/5.00), suggesting feasibility for real-world adoption. Crucially, participants evaluated the ability to independently explore construction scenarios (Question D) at 4.00/5.00, directly supporting the study's objective of restoring practitioner agency during the Setup phase. Table 2 summarizes the quantitative results.

Table 2. Summary of quantitative survey results (N = 5)

Metric	Related activity	Mean score (max 5.0)
Improvement in stakeholder communication (Q B)	*Nemawashi*	4.40
Improvement in quantity verification (Q C)	*Dandori*	4.40
Ease of operation (accessibility)	–	4.00
Ability to explore independently (agency)	–	4.00
Intention to use	–	4.00

5.4.1 Quantitative Efficiency Improvements

To further clarify the significance of the proposed workflow in relation to conventional practice, a small comparative time observation was conducted during the pilot workshop. Using one construction zone from a previously completed project prepared as workshop material, two participants were asked to count three structural element categories—columns, primary beams, and secondary beams—on 2D drawings using markers. The measured time per element category ranged from 3 to 9 minutes. This variation suggests that manual quantity take-off is partly operator-dependent, for example depending on whether the count is performed once or repeated for verification to avoid omissions.

Using the upper-bound value as a conservative estimate, counting three element categories for one floor would require approximately 27 minutes, and extending the same procedure across seven floors would require approximately 189 minutes. Although this was only a limited comparison, it indicates that the conventional workflow involves both substantial time burden and variability between operators.

By contrast, the proposed workflow enabled equivalent quantity verification and generation of 4D visual outputs in approximately 15–20 minutes. The time required for regeneration depended on the scale of the revision: minor modifications—such as resizing Box mass elements in Revit or changing the correspondence between schedule items and work zones—required approximately 2–5 minutes, whereas major modifications—such as changing the total number of work zones or restructuring the schedule in GaNett—required approximately 15–20 minutes.

In current practice, such full regeneration is rarely undertaken. The significance of the proposed workflow therefore lies not only in reducing task duration, but in making iterative scenario re-examination practically feasible for site engineers themselves.

5.5 Qualitative Observations from Open-Ended Responses

Open-ended responses further clarify why the workflow was valued. Participants noted that the system helped them interpret planning logic spatially and that the flipbook-style 4D outputs were easy to use when explaining plans to stakeholders who do not use BIM tools. Several participants also highlighted that rerunning the workflow after small schedule changes enabled "what-if" discussions during coordination meetings.

Importantly, multiple comments reflected a shift in perceived role: instead of waiting for BIM specialists to prepare visualisations, participants felt able to check scenarios by themselves and confirm whether the plan was reasonable at an early stage. These observations align with the quantitative ratings on independent exploration, supporting the interpretation that accessibility—rather than automation speed or visual fidelity—was the primary source of value.

5.6 Summary of Evaluation Results

The evaluation results indicate that the proposed schedule-driven lightweight 4D simulation workflow addresses perceived challenges in Setup-phase planning.

Participants reported that the workflow supports both *dandori*-oriented quantity verification and *nemawashi*-oriented stakeholder communication, while remaining accessible to practitioners without advanced BIM expertise. Taken together, the quantitative ratings, comparative observations, and qualitative responses suggest that lowering barriers to BIM-based 4D reasoning can restore practitioner agency and enable more repeatable and revisable planning cycles during the Setup phase. The workflow's value therefore lies not merely in automation speed, but in making practitioner-led iteration practically feasible.

6 Discussion

6.1 Restoring Practitioner Agency in the Setup Phase

The evaluation results indicate that the proposed schedule-driven lightweight 4D simulation workflow contributes to restoring practitioner agency during the Setup phase. Rather than positioning site engineers as passive recipients of BIM outputs generated by specialists, the workflow enables them to directly interact with spatial and temporal information and to explore construction scenarios independently.

This shift is particularly significant in the context of Setup-phase activities such as *dandori* and *nemawashi*, which require frequent iteration, negotiation, and validation. Participants valued the ability to "check by themselves" and to rerun the workflow after small schedule changes, supporting rapid "what-if" exploration. The quantitative results also suggest a positive perceived ability to explore scenarios independently (agency), consistent with this observation. These findings suggest that agency in this context is not defined by advanced modelling capability, but by the ability to access, interpret, and manipulate relevant process information at the moment decisions are made.

From this perspective, the proposed workflow does not merely automate existing tasks; it reconfigures the relationship between practitioners, BIM models, and planning decisions. By lowering barriers to engagement with BIM-based 4D information, the system allows agency to shift from specialists toward site-level practitioners who are directly responsible for coordination and execution.

6.2 Accessibility as a Design Principle for 4D Systems

A key contribution of this study is the articulation of accessibility as a central design principle for 4D simulation systems. The lightweight PIM operationalizes accessibility across three dimensions—cognitive, technical, and operational—providing a concrete framework for evaluating and designing practitioner-facing tools.

The evaluation results suggest that reducing these barriers can yield tangible benefits, even with a small-scale pilot. Participants reported high perceived usefulness and ease of operation, despite limited prior experience with BIM authoring. Importantly, the system's value was associated more strongly with accessibility and iteration speed than with visual fidelity or automation sophistication. This finding challenges the prevailing assumption that effective 4D systems must prioritize realism or optimization. Instead, for Setup-phase planning, the ability to quickly generate understandable visual evidence and to iterate collaboratively may be more critical than producing detailed simulations.

6.3 Limitations

This study has several limitations. First, the evaluation was a small-scale pilot (N = 5) in a single organization and therefore does not support statistical generalization. However, the workflow targets approximately 40–50 potential users in the organization, and the pilot cohort was selected to reflect variation in BIM usage frequency and understanding; thus, the findings should be interpreted primarily as evidence of feasibility and perceived usefulness.

Second, the study focused on Setup-phase activities and did not assess downstream impacts on Execution or Control (e.g., productivity or schedule reliability).

Third, the workflow was evaluated using simplified Box mass representations; future studies should test scalability with more complex models and coordination settings.

Fourth, although the system supports L-shaped and other non-rectangular mass geometries, zones containing interior voids (e.g., donut-shaped regions) still require manual workarounds. Moreover, spatial filtering is applied uniformly to all elements within a zone, and does not support element-type-specific selection (e.g., columns only), which limits the representation of phased erection sequences.

Therefore, semi-automated zone generation and element-type-based filtering remain important areas for future development.

6.4 Implications for Future Research and Practice

Despite these limitations, the lightweight PIM concept opens directions for comparative studies across projects and cultural contexts. For practice, embedding digital support within existing site workflows can expand practitioner access to BIM-based reasoning without requiring adaptation to complex authoring environments. Following this formative pilot, we will conduct additional workshops to evaluate scalability across a broader range of roles and BIM literacy levels.

7 Conclusion

This study addressed a persistent gap between the availability of BIM models and their practical use in Setup-phase construction planning. While BIM and 4D simulation have been widely promoted, their adoption during *nemawashi* and *dandori* activities has remained limited due to heavy reliance on BIM specialists and the lack of accessible practitioner-facing tools.

To respond to this challenge, the study proposed a schedule-driven lightweight 4D simulation workflow grounded in a Design Science Research (DSR) approach. Building on the Four-fold Framework for Process Information Management, the system operationalized a lightweight Process Information Model (PIM) that prioritizes accessibility across cognitive, technical, and operational dimensions. By treating schedules as the primary driver and BIM geometry as a verification and visualisation medium, the workflow aligned digital support with how planning decisions are actually made in practice.

Evaluation through a pilot workshop suggested that the proposed workflow can effectively support Setup-phase activities. Participants reported improvements in zone-based quantity verification and stakeholder communication, as well as a strengthened ability to independently explore construction scenarios. These results suggest that the value of 4D simulation in this context lies not in high-fidelity visualisation or advanced automation, but in enabling practitioner-led iteration and decision-making.

The primary contribution of this research is the articulation and empirical grounding of restoring practitioner agency as a key objective for digital tools in construction planning. Rather than replacing human judgment, the proposed system repositions BIM-based 4D information as a resource that site engineers can directly access, interpret, and use to negotiate planning decisions during the Setup phase.

From a broader perspective, this study suggests that accessibility-focused design can play a critical role in bridging the gap between planning intent and executable site actions. By lowering barriers to BIM-based reasoning, lightweight systems such as the one presented here have the potential to support more resilient, field-driven Production Planning and Control practices. Future research can extend this work by examining longitudinal impacts on project performance and by exploring how lightweight PIM concepts transfer across different organizational and cultural contexts.

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