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TRANSLATING 5S PLANNING INTO PHYSICAL SITE PRACTICES THROUGH BIM-BASED VISUALIZATION: A CASE STUDY OF THE BRI RAGUNAN BUILDING PROJECT

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ABSTRACT

Projects with storage constraints face issues like unclear material locations, excessive materials shifting, and poor waste handling. Although the 5S concept is not new in the Lean Construction movement, it is not easy to implement on-site. This paper aims to explore the integration of 5S-based storage planning with the visual medium of BIM, which can make it more embedded in the site process. The process follows three steps: using 5S to plan the storage locations, converting the 5S plan into BIM, and finally visualizing the plan on-site using paper media and visual aids. In this paper, BIM was used as a visual management tool, not for automating or managing inventories. The findings suggest improved material flow clarity, reduced unnecessary movement, and better identification of reusable waste materials. The study demonstrates that effective Lean implementation can be achieved through simple planning decisions reinforced by visual tools that connect digital models with physical site practices.

KEYWORDS

5S, BIM, visual management, material flow, waste management.

INTRODUCTION

Construction projects worldwide consistently encounter inefficiencies in the management of construction materials. There is excessive movement of materials, material search time,

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interruptions in the workflow, and waste generated in construction projects, even with the use of advanced construction technologies (Song et al., 2006; Ergen et al., 2007; Ajayi et al., 2015). Recent research has indicated that the management of materials in construction projects has a significant effect on the amount of waste generated (Yıldız et al., 2024; Abkar et al., 2024). Based on the principles of Lean construction theory, any extra movement or transportation is not value-adding to the construction process (Koskela, 1992; Sacks et al., 2010).

The project delivery method, particularly Design and Build (D and B), significantly influences material flow and coordination. Although the D and B project improves integration compared to traditional systems (Konchar and Sanvido, 1998; Hale et al., 2009), overlapping design and construction could facilitate coordination uncertainties when information is incomplete. Design revisions and procurement changes may disrupt supply chain reliability and on-site logistics (Love et al., 2014; El Asmar et al., 2013), while limited stakeholder integration further increases material flow variability (Vrijhoef and Koskela, 2000; Eriksson, 2015).

Lean workplace organization techniques are employed to maintain workflow stability and material visibility in changing conditions. The 5S techniques of Seiri, Seiton, Seiso, Seiketsu, and Shitsuke provide a framework for organizing the workplace to eliminate unnecessary movements in the workplace (Koskela, 1992). Sustaining 5S implementation in the construction industry is particularly challenging in D and B projects due to dynamic and evolving project conditions. Previous empirical studies in construction have demonstrated that disciplined 5S implementation can significantly improve performance outcomes such as safety, health, and quality, reinforcing the value of workplace organization in Lean contexts (Sasongko et al., 2025). Building Information Modeling (BIM) addresses this problem by enabling visualization of a spatial layout, storage areas, temporary facilities, and work processes in a single environment (Sacks et al., 2010).

BIM has evolved from its use in construction planning and logistics management (Bortolini et al., 2015; Hamledari and Fischer, 2020), enabling a visualization approach that is in line with Lean philosophy. The problem is that there is a lack of research on integrating BIM and 5S tools in a fast-paced environment of D and B projects. The present research addresses this problem by exploring BIM-based 5S implementation in a D and B construction project in Indonesia. The research is based on a case study approach (Yin, 2018), and is intended to assess its effect on key performance indicators—searching for materials, working distance, misplaced materials, and waste management—in line with the principles of Lean philosophy, aiming to eliminate non-value-added activities and reduce variability (Koskela, 1992; Sacks et al., 2010).

This study contributes to Lean Construction and digital construction management literature by proposing and empirically validating a practical framework for integrating BIM and 5S as a visual management strategy in space-constrained and dynamic construction environments. The findings provide theoretical insight into BIM–Lean operational alignment and practical guidance for sustaining lean practices through digital support mechanisms.

LITERATURE REVIEW

MATERIAL MANAGEMENT INEFFICIENCIES IN CONSTRUCTION

Material management has been identified as one of the major determinants of construction projects. Inefficiencies in material management, including excessive material movements, search times, and misplacement of materials, have been shown to negatively affect construction productivity and result in excessive waste (Song et al., 2006; Ergen et al., 2007; Love et al., 2014). In terms of supply chain management, fragmentation of stakeholder coordination has been identified to negatively affect material management (Vrijhoef and Koskela, 2000; Eriksson, 2015). Recent studies have found material management to be crucial to time efficiency and reduction of waste (Yıldız et al., 2024; Abkar et al., 2024).

DESIGN AND BUILD CONTEXT AND COORDINATION COMPLEXITY

Project delivery methods play a crucial role in material management. The D and B method has been identified to allow for greater integration between construction players than traditional methods (Konchar and Sanvido, 1998; Hale et al., 2009). In this method, design and construction occur simultaneously, which may result in coordination complexities due to the dynamic nature of information during construction (Love et al., 2014; El Asmar et al., 2013). Such complexities may affect the stability of site organization; hence, proper coordination between the D and B methods and material management is crucial.

LEAN CONSTRUCTION AND 5S FOR MATERIAL FLOW STABILITY

Lean Construction understands the production process as a flow-based system, emphasizing that excessive movement, waiting, and transportation are not value-added activities that decrease the efficiency of the process (Koskela, 1992; Sacks et al., 2010) In this context, the organization of the construction site plays a critical role in stabilizing material flow, while the 5S methodology helps minimize search time and unnecessary movement through systematic workplace organization (Sacks et al., 2021). However, the dynamic nature of design–build (D&B) projects, characterized by continuous design development and procurement changes, can destabilize standardized site arrangements and limit the long-term sustainability of 5S practices (Sacks et al., 2021). To address this challenge, a BIM-supported 5S planning framework was developed to translate Lean workplace organization principles into spatially explicit construction site configurations (Sepasgozar et al., 2021; Zubair et al., 2024).

BIM AS A DIGITAL ENABLER FOR LEAN VISUAL MANAGEMENT

BIM can be used to support planning, coordination in spaces, and logistics through the integration of spatial information with schedule information to increase transparency in material allocation and temporary spaces (Hamledari and Fischer, 2020; Bortolini et al., 2015). Studies have proven that BIM-Leans can increase workflow reliability and information flow (Sacks et al., 2010). However, literature reviews have shown that there is increasing interest in BIM-Leans, especially in scheduling rather than operational workplace organization tools (Alnajjar et al., 2025; Yang et al., 2025). Empirical studies have proven the performance enhancement potential of BIM-Leans (Hei et al., 2024); however, there is a lack of studies on BIM-Leans in the institutionalization of 5S spaces in dynamic D and B projects.

RESEARCH GAP AND THEORETICAL POSITIONING

Based on the research gaps identified in material handling efficiency, coordination variability in D and B projects, and the lack of studies on the use of 5S in BIM-Leans in visual planning, a gap in the theories on how BIM can be used to sustain 5S spaces in material flow stability in dynamic D and B projects exists. This research aims to address this gap by investigating a BIM-based 5S framework in a Design-Build project in Indonesia. contributing to both Lean Construction theory and digital construction management practice.

METHODOLOGY

This study adopts a case study–based observational research approach to examine the implementation and effects of BIM-based 5S planning on material and waste management in a space-constrained project. A case study approach is considered appropriate for investigating construction environments characterized by high levels of uncertainty, frequent design changes, and strong interdependencies between design, logistics, and site operations, as commonly found in D and B projects (Daniel et al., 2024).

Field observations were cross validated through physical counting, photographic documentation, and comparison with logistics delivery records. The consistency between

recorded data and physical verification improved measurement precision and enhanced data reliability.

CASE STUDY OBSERVATION

The case study was conducted at one of the buildings in the BRI Ragunan IT Center Area Development in South Jakarta, Indonesia. The building features a vertically typical floor layout; therefore, the 6th and 7th floors were selected as a representative level due to active finishing works during the observation period. The study focused on wall finishing activities, as these constituted the dominant material-intensive operation within the constrained service work scope. The project presents characteristics that make it a representative case for this research:

- Limited on-site storage capacity, requiring precise material allocation
- Lack of structured material zoning led to scattered storage and inefficient handling
- Typical of D and B environments, which have concurrent design and construction processes, leading to frequent design updates and procurement adjustments

These conditions reflect common challenges in urban construction projects and provide a suitable setting for evaluating Lean-based material management strategies supported by BIM.

BIM-BASED 5S INTERVENTION AND EVALUATION

Given that the project had not previously adopted 5S principles, Lean workplace organization was translated into a BIM-based 5S framework to serve as both an intervention and an evaluative comparison against pre-implementation conditions. Using BIM as a visual management platform, the site layout was reorganized into clearly defined zones, including active material storage zones, buffer and temporary holding area, and waste and reusable material zones. The zones were digitally modelled and integrated into the construction planning workflow. The BIM-generated layouts were then deployed on-site through printed layout drawings, physical zone labelling, and visual communication boards, ensuring alignment between planned spatial organization and actual site implementation, thereby reducing ambiguity in material placement and movement.

DATA COLLECTION AND MEASUREMENT

Construction production systems are inherently variable, and single-day measurements may not represent typical workflow behavior (Koskela, 2000). Distributing observations over multiple days enhances construct validity and provides a more representative assessment of flow stability (Yin, 2018). Observations were conducted over ten working days (five before and five after intervention) under comparable work stages and material demand conditions, with daily recording of material placement, waste separation, and handling conditions without any omission of data. This enabled a comparative evaluation between two datasets: the original layout without 5S implementation on the 6th floor and the reorganized layout applying BIM-based 5S principles on the 7th floor. Data were cross-validated through physical counting, photographic documentation, and comparison with logistics records to enhance reliability.

Four key performance indicators (KPIs) were selected based on Lean Construction principles and prior literature:

- Material Search Time: Measured using repeated stopwatch observations during material retrieval activities. A total of ten comparable observations were conducted.
- Material Flow Distance: Quantified using spatial analysis within the BIM model by identifying movement paths between work zones. These estimations were verified through on-site walkthrough observations.

- Misplaced Material Incidents: Recorded through daily site inspections and documented in weekly logs. Incidents refer to materials found outside designated zones or requiring re-handling.
- Material Waste Identification and Reuse: Observed through visual inspection of waste conditions.

To reduce measurement bias, observations were conducted at comparable work stages and cross-validated with the site supervisor and logistic personnel.

DATA ANALYSIS

The analysis adopts a comparative, descriptive, and analytical approach, focusing on identifying performance changes between pre- and post-intervention conditions. The evaluation includes:

- Average comparison of observed values across measurement sets
- Percentage improvement analysis to quantify performance changes

Given the limited sample size, the study emphasizes pattern consistency and practical relevance rather than statistical inference. Quantitative findings are supported by qualitative input from site personnel regarding behavioral adjustments and operational changes.

RESEARCH LIMITATIONS

This research has some limitations. First, the research is based on one case study, which becomes a limitation. Second, although cross-validation methods were adopted, the use of an observational approach is likely to have some level of subjectivity. Third, the research has limited data, which limits the use of sophisticated statistical analysis.

Despite the limitations, the research is useful in providing an understanding of the application of BIM and Lean concepts in the real world. The research can be improved by the use of a large amount of data and sophisticated statistical analysis.

ANALYSIS

The key concern revolved around the unmanaged placement of materials and waste placement in a space-constrained finishing area, causing flow interruptions and inefficient handling. Lean principles were applied for observation analysis, and BIM helped in restructuring space for stability in flow and minimizing placement-related issues. Table 1 links identified problems to relevant 5S elements and BIM-based interventions. Initial findings show improvements in material identification, reduced motion waste, enhanced reuse awareness, and better stock visibility, demonstrating the practical integration of Lean principles and BIM implementation.

Table 1: Problem Identification and the Observed Outcome

Site Problem	Lean Principle (5S)	BIM Support	Observed Outcome
Unclear Material Location	Seiton (Set in order)	Floor- and zone-based visualization	Faster material identification
Reactive procurement	Seiketsu (Standardize)	Stock visibility vs demand window	Early warning before stock-out
Excessive worker movement	Seiri (Sort)	Organized storage zones	Reduced motion waste
Discarded Waste Material	Seiso (Shine)	Dedicated waste/reusable zones	Improved reuse awareness

It should be noted that Table 1 primarily captures operational evidence for four elements of 5S. The fifth element, Sustain (Shitsuke), requires longer-term behavioral consistency and cultural embedding, which could not be fully assessed within the short intervention period. This limitation is acknowledged and suggests the need for longitudinal evaluation of BIM-supported 5S implementation.

APPLYING 5S TO MATERIAL AND WASTE MANAGEMENT

The 5S principles were applied as practical guidelines for construction environments with dynamic schedules. Before defining material layouts, the project context—including the 3D building and site model, integrated schedule, material elements, and available work zones—was analysed to align material placement with spatial and construction requirements.

The materials were then organized based on the order in which they were used and how often they were needed. Commonly used items were kept close to where people work, and not-so-used materials were put in separate storage areas. Reusable and non-reusable waste were sorted into specific areas to reduce the need for handling multiple times and make it easier to check during inspections.

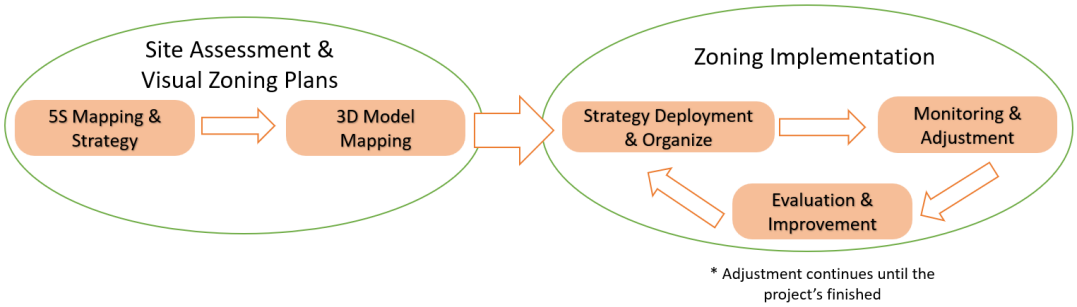

Figure 1: Workflow of BIM-based 5S implementation

Figure 1 shows the workflow with two phases of Site Assessment and Visual Zoning, and Zoning Implementation. The workflow begins with 5S mapping and strategy development. The strategy developed will be transformed into BIM by three-dimensional model mapping to visualize the storage zones and spatial configurations. After that, the strategy will be executed on site with monitoring, evaluation, and adaptation. This sequence of operations will ensure the effective implementation of 5S planning.

Following the completion of material placement planning, the strategy was implemented on-site and continuously monitored. Given the high level of schedule and design fluidity inherent in D and B projects, adjustments to material placement were occasionally required. The approach emphasized flexibility, allowing material storage arrangements to be updated in response to changing site conditions and evolving owner requirements, while maintaining the overall structure defined by the 5S framework.

BIM AS A SUPPORT TOOL FOR 5S LAYOUT PLANNING

According to the coordination meeting and data cross-validation with the site supervisor and logistic personnel, the zones were divided into three types: active material storage zones, buffer and temporary holding area, and waste and reusable material zone, as mentioned in Figure 1.

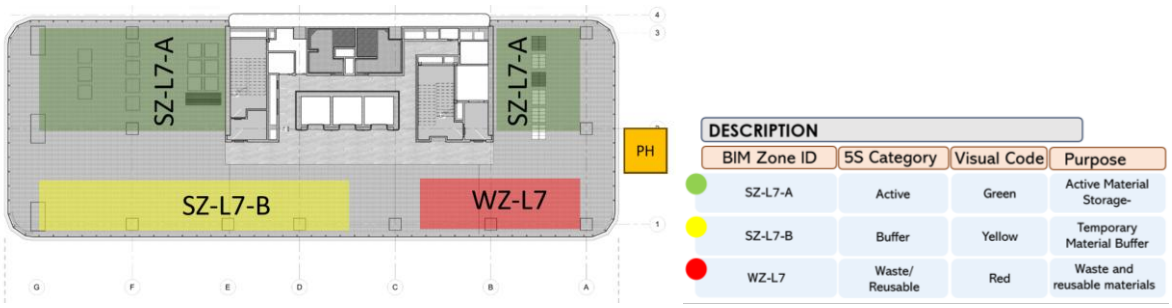

Figure 2: Material placement layout

As illustrated in Figure 2, two storage zones for active material were identified on the left and right sides of the work zone, measuring respectively 128 m² and 64 m², totalling 192 m². A buffer and temporary holding area measuring 104 m² was placed adjacent to the work zone, while the 56 m² waste and reusable material zone was located within the work area and near the lifting access point to facilitate material removal. Following the zoning configuration, the BIM-generated layout was adopted as the on-site reference. To ensure effective communication to field personnel, the spatial information was translated into deployment media, as summarized in Table 3.

Table 3: Physical deployment of BIM-based layout on site

Deployment Media	Location	Content	Purpose
Printed layout (A3)	Storage area	Floor layout with 5S zones	Fixed location reference
Zone labels	Storage racks	Zone ID and function	Prevent misplacement
Information board	Floor access	Simplified BIM snapshot	Daily worker reference

The zone coding system in Table 3 established a consistent visual reference, standardizing material handling and aligning the site personnel's understanding. Workers followed a clear pattern—identifying materials, retrieving them from designated zones, and transporting them directly to the work area without intermediate searching. This workflow formed the basis for evaluating material search time and movement distance as indicators of BIM-based 5S effectiveness. The deployment of this visual system is illustrated in Figure 2 and served as the operational reference for implementation.

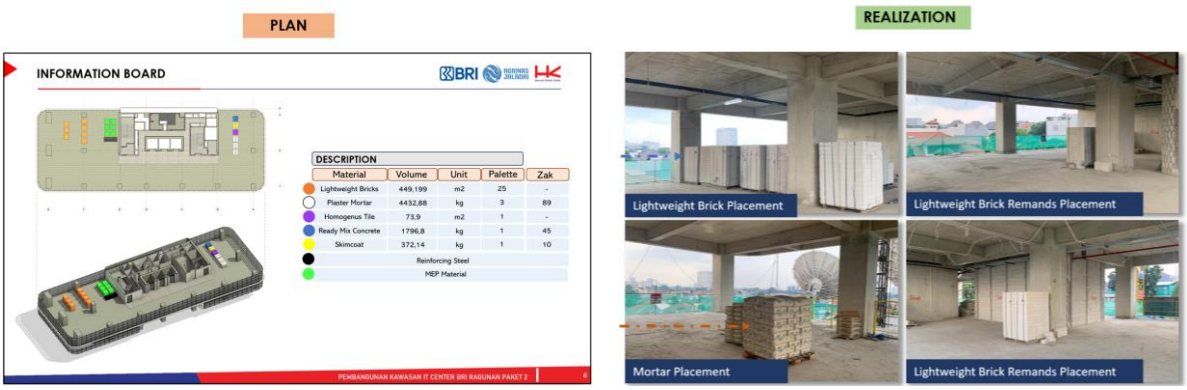

Figure 3: Material placement plan using BIM models

Following the divided zones, the figure illustrates the integration between planning and on-site realization of BIM-based 5S zoning. The left side presents the planned material layout within the BIM model, where storage zones are defined and color-coded according to material type, along with summaries of material quantities and pallet allocations for the selected floor,

providing a structured reference to support control storage, clear identification, and efficient material flow management. The right images showing the physical implementation of these zones on site.

RESULTS

Activities with high material utilization, such as ceiling installation, wall, and tiling, showed more stable progress after the implementation of 5S-based material planning. These measures resulted in reduced search and handling, better separation, and availability of materials, which all contributed to site organization and increased efficiency.

Table 4: Material search time and flow distance (Before vs After)

Observation	Before (min)	After (min)	Reduction (%)
Day 1	12	4	67%
Day 2	10	3	70%
Day 3	15	5	67%
Day 4	11	4	64%
Day 5	13	4	69%
Average	**12.2**	**4.0**	**67%**
Condition	**Avg. Zones Passed**	**Approx. Distance (m)**	**Observed Cases of Misplaced Material Incidents**
Before	4–5	40–50	7
After	1–2	10–20	2

Based on the analysis presented in Table 4, the average material search time before the implementation of BIM-based 5S was 12.2 minutes. After implementation, it decreased to 4.0 minutes, representing a 67% reduction. The flow distance analysis indicates that the average number of zones passed before implementation was higher than after implementation. Similarly, the approximate travel distance in the pre-implementation condition was longer compared to the post-implementation. Misplaced material incidents were also more frequent before the intervention. A consolidated summary of these comparative findings is presented in Table 5.

Table 5: The summary of observed Before–After indicators

Indicator	Before	After	Measurement Basis
Avg. material search time	12.2 min	4.0 min	10 observations
Avg. movement distance	40–50 m	10–20 m	Zone-based estimation
Misplaced material cases	7	2	Weekly observation

The results showed improvements in the processes after implementing 5S along with BIM visualization. These improvements during the process have confirmed the effectiveness of implementing the Lean-BIM approach. This study corroborates previous studies on the application of the Lean-BIM approach, which have shown improvements in material accessibility using BIM visualization (Pandit, 2022). The improvements in waste separation also align with previous studies conducted on the application of BIM for effective waste management and reuse (Fitriani et al., 2023; Yousif et al., 2021).

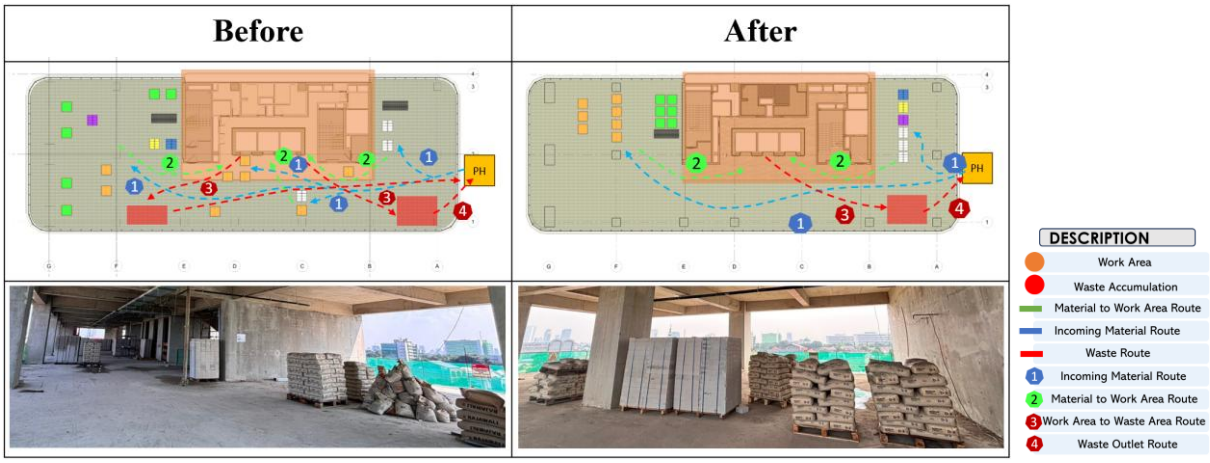

Figure 4: the before and after of the BIM-based 5S material placement implementation

Figure 4 compares site conditions before and after the BIM-based 5S implementation. Initially, materials and waste were dispersed without clear zoning, causing overlapping routes and inefficient movement. After zoning optimization, materials and waste were placed in designated areas with more direct routing paths, reducing movement conflicts and improving flow stability within the constrained workspace. Following the results of the implementation of 5S-based BIM on material placement, implementation in waste management also shows similar results, as presented in Table 6.

Table 6: The before and after effect of 5S + BIM Implementation

Before

Material	Unit	Estimated Waste	Detected	Reusable	Disposed
Ready-Mix Concrete	m^3	101,74	27,47	10,60	91,14
Reinforcing Steel	kg	22.705,16	6.130,39	2.366,42	20.338,74
Lightweight Bricks	m^3	48,36	13,06	5,04	43,32
Plestering Mortar	kg	131.148,67	35.410,14	13.662,87	117.485,80
Homogeneous Tile	m^2	5,18	1,40	0,54	4,64

After

Material	Unit	Estimated Waste	Detected	Reusable	Disposed
Ready-Mix Concrete	m^3	66.13	60.12	31.56	34.57
Reinforcing Steel	kg	14,758.35	13,417.59	7,046.66	7,711.69
Lightweight Bricks	m^3	31.43	28.57	14.99	16.44
Plastering Mortar	kg	85,246.64	77,497.86	40,691.02	44,555.62
Homogeneous Tile	m^2	3,37	3,06	1,61	1,76

As shown in Table 6, waste management before implementation was largely reactive, with most materials directly disposed of without systematic identification. After the BIM-based 5S intervention, designated zones and visual controls improved waste detection and reuse assessment, reflecting a more structured Lean approach. Summarizes the material-level

findings into key performance indicators, highlighting that the overall improvement in waste management efficiency can be seen in Table 7.

Table 7: The summary of waste condition before 5S + BIM implementation

Indicator	Before	After
Waste detected (%)	27.1%	90.9%
Reusable identified (%)	10.4%	47.7%
Direct disposal (%)	89.6%	52.3%
Total estimated waste (normalized)	100%	65%
Waste reduction rate	–	35% ↓

The before-and-after percentage presented in Table 7 demonstrates the opportunities for waste reuse enabled by improved waste detection. The smaller number of waste items disposed of in the process implies that the items previously considered waste were re-assessed and utilized wherever possible, thereby demonstrating the effectiveness of the visualization-based approach. Other studies suggest that tracking waste and using visual aids for waste sorting and reuse on construction sites are effective (Zhao et al., 2025; Bukovics, 2025).

DISCUSSION AND CONCLUSION

This research contributes to Lean Construction by positioning BIM-based 5S planning as a digital visual control mechanism for stabilizing material flow in space-constrained D and B environments. By integrating 5S with BIM, material placement becomes spatially codified, reducing handling variability and reinforcing flow stability, which are core principles of Lean Construction. Rather than treating BIM as a productivity aid, this study conceptualizes it as a socio-technical enabler that enhances transparency and systematic waste reduction, extending prior Lean–BIM research (Sacks et al., 2021; Sepasgozar et al., 2021). Spatializing 5S planning reduced ambiguity in material placement and strengthened material governance, consistent with findings that poor 5S practices contribute significantly to waste (Sepasgozar et al., 2021; Zubair et al., 2024).

Aligning zoning logic with construction sequencing further minimized waiting waste, in line with Lean flow stabilization principles (Sacks et al., 2021). Within this framework, BIM served as a spatial validation and quantification platform, enabling scale-accurate coordination and measurable estimation of material-flow distances. Although the focus remains on spatial organization, the model provides a pathway toward 4D and takt-based planning, positioning BIM as an integrative Lean implementation platform.

The results indicate improved standardization; however, sustainment (Shitsuke) depends on norm internalization over time. Due to the limited observation period, long-term sustainment could not be comprehensively assessed. Research shows that improved material supply and stock control enhance time efficiency (Yıldız et al., 2024), consistent with the schedule acceleration observed in this study. The performance of the schedules was affected by various factors, but it resulted in the advancement of the planned completion date, from April 2026, it moved forward to December 2025, which is an estimated efficiency improvement of about 18.7%.

This research offers BIM-based 5S planning as a digital approach of visual control for material flow stability in Lean Construction. Through its integration of spatial zoning with BIM, it improves material transparency, maintains separation discipline, and supports material flow stability, thus embedding the fundamental principles of Lean Construction (Sacks et al., 2021; Sepasgozar et al., 2021). Although based on a single case study, it is applicable on a larger scale

for space-constrained D&B projects and offers scope for integration with scheduling and purchasing systems (Zubair et al., 2024).

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