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Improving construction efficiency through lean techniques and digital tools: case of a real-time implementation in an institutional building construction

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Introduction: Constructions continue to be plagued with waste, cost-overrun, delays and poor real-time coordination. However, the integrated implementation of both lean construction and digital tools (e.g. BIM, business intelligence) have not been extensively investigated under real-time project settings despite their respective capabilities in boosting performance.

Methods: This research utilised a Lean–Digital integrated methodology in the context of a building project at an institutional scale located in Vellore. Activities were categorized as value-adding (VA), non-value-adding (NVA) and necessary non-value-adding (NVAN) using Value Stream Mapping (VSM). A 4D/5D BIM model in Autodesk Revit was synchronised with Power BI dashboards via Speckle for online monitoring. Workflows (Power Automate) were built to create automatic alerts and approvals. Performance was tested in the field during a 4-month observation period.

Results: Lean construction interventions decreased the duration of excavations by 15% and saved 2.06% (234.88hours) total in a project's time span. Real time digital dashboards led to better communication with parties involved, minimized delays in approval and constituted more transparency in monitoring progress. The automated workflows accelerated reporting cycles and increased agility in the decision-making process.

Discussion: The findings demonstrate that integrating lean process optimization with digital monitoring platforms creates measurable efficiency gains and enhances proactive project management. The proposed framework supports data-driven decision-making and offers a scalable model for improving construction productivity through synchronized Lean–Digital implementation.

KEYWORDS

construction management, lean construction, lean-BIM integration, power BI, value stream mapping

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1 Introduction

The construction industry is still facing the chronic problems of efficiency, cost overruns, project delays, and underutilization of resources. Conventional project management practices in the industry are reactive: they lack structured protocols for systematically detecting sources of waste or monitoring work site conditions on a real-time basis. New digital and lean construction tools have the potential to produce significant productivity gains to address these four challenges.

Lean construction aims to identify where to add the value and remove the waste in the construction value chain (Ramani and Lingan, 2019). Value Stream Mapping (VSM), a lean tool for analyzing and redesigning the process segregates the activities into those adding value and those that do not add value to the operation and practices in this context. As a recent trend, waste categories like material handling and approval lags are targeted by VSM deployment in construction, which brings about reduction in project cycle times especially at the downstream end (Morato and Ferreira, 2024). To complement the above and to fit waste reduction into the overall realm of smart sustainable development, VSM has also been used to map environmental and social aspects in a recent study (Batwara et al., 2023). At the same time, with its shared and data-rich virtual representation of the functional and physical characteristics of a project, Building Information Modeling (BIM) has also driven technological adoption in the construction sector to a great extent. The potential of BIM can be multiplied when it is complimented by Business Intelligence (BI) tools like Power BI (Mane and Mhaske, 2024).

Some studies suggest that by connecting BI dashboards with BIM data, transparency and early identification of project deviations can be achieved (Di Giuda et al., 2024; Gajera, 2023). The digital twin, enabling the cloud-based real-time synchronous connection with predictive analyses and improving lean management capacity, defines this further evolution as the next stage (Jiang et al., 2024; Owais et al., 2024). Lean implementation is prevalent, and digital tools have had success; however, it is not known to its full extent how end-to-end integration of Lean concepts with digital tools can produce a synergy effect.

This paper investigates how a lean-digital approach was put into practice on a major institutional building project. It carefully examines how well VSM works for process optimization and how BIM, Speckle, Power BI dashboards, and Power Automate workflows can be used in tandem to improve stakeholder participation, transparency, and communication. To provide data-driven insights into the measurable benefits of leveraging both lean and digital tools to improve construction project delivery, this paper provides an actionable case study.

Although tools and techniques from the Lean methodology, such as VSM are widely used for non-value-added activities identification in construction and despite the advances made by a significant number of LCM studies across various industry sectors we have found that research, practical recommendations in terms of theoretical implementation and integration with digital real-time monitoring systems remain limited. Likewise, planning and visualization-tools for BIM used on the building site are widespread, but there is a lack of empirical validation to what extent they actually affect measurable performance throughout the project and production feedback loops. In construction, however, both process optimization focusing on inefficient processes and real-time data sharing, monitoring and decision-making are necessary in practice. Hence, in this work. We attempted to fill this gap by presenting and applying an integrated Lean–Digital framework consisting of VSM, BIM modeling, Speckle-based data sync., and Power BI dashboards for monitoring measurable project performance indicators on an ongoing project in Vellore. The proposed process is validated through a 4-month field observatory period, which provides quantitative measurement such as time saving in the excavation process and sensor-on time to communication latency: RFI response within two working days.

2 Literature review

Two complementary streams of recent research on construction efficiency are the use of data-driven digital platforms for real-time project visibility and control and the application of lean methodologies such as VSM to identify and eliminate process waste.

Several VSM applications in construction are identified by Morato and Ferreira (2024) through a systematic review, indicating that the application of the methodology in an iterative manner with the stakeholder involvement has generally been able to deliver reductions in cycle frequency. This reinforces that VSM is a successful tool to find and remove wastes such as downtime, material travel, and approval waits. Towards smart and key sustainable development goals for systematic removal of the waste, studies on recent perspectives widen this basis by incorporating environmental and social perspectives into VSM (Batwara et al., 2023). According to Michaud et al. (2019), VSM could be effectively applied to digital processes themselves, e.g., streamlining BIM information flows in order to minimize the amount of time it requires for data transfer.

On the digital side, however, the most important factor influencing data management is the combination of BIM and BI. According to research, connecting BIM data to Power BI dashboards enables planners to see time (4D) and cost (5D) optimization centrally and interactively, allowing them to see departures much earlier (Mane and Mhaske, 2024). This solution enhances real-time cost tracking and data insights by enabling drill-down exploration for managers (Gajera, 2023). More refined BIM-BI integrations for facility management can be realized through advanced applications, where complex model-based data can be translated into extensive dashboards for informed decision-making (Di Giuda et al., 2024; Roxo et al., 2022).

The crossover of these digital technologies that integrates lean principles for real-time visibility and predictive analytics is an area on the rise. Digital solutions enable dynamic construction process visualizations that help teams identify non-value-added activities and promote teamwork and transparency (Owais et al., 2024). This idea develops from static models into a Synchronized Construction Management agenda and provides strategies for connecting the virtual twin model and the physical site in real time (Jiang et al., 2024). Additional technological developments can include employing open BIM standards to guarantee data verification continuously throughout a project's life cycle (Otranto et al.,

TABLE 1 Representative studies (methods and outcomes).

Source	Context	Methods	Reported outcomes
Newhouse et al. (2025)	Enterprise visibility challenges with TLS 1.3	High-level document analysis	Best practices for TLS 1.3 visibility
Liu et al. (2025)	BIM, IoT, and GIS integration in resource monitoring	Case study; dashboard implementation	Real-time monitoring of resources
Otranto et al. (2025)	Open BIM solutions for FM interoperability	Survey; solution prototyping	Improved operations efficiency
Rehman et al. (2025)	Game engine–BIM integration in AEC	Mixed-method interviews and experiments	Identified integration challenges
Jiang et al. (2024)	Digital twin–enabled synchronized construction management	Roadmap development; literature review	Prospects for construction 4.0
Abdelghany and Shokri (2021)	BIM as a lean management tool	Case study	Waste reduction in construction processes
Abedini et al. (2021)	BIM and digital twinning for lean practices	Experimental framework; pilot implementation	Sustainable construction improvements
Aliakbar et al. (2024)	BIM to digital twin conceptual framework	Conceptual modeling; framework validation	Enhanced interoperability
Owais et al. (2024)	Digital twins enabling lean construction levels	Conference proceedings; simulation-enabled VSM	Lean process improvements
Di Giuda et al. (2024)	BIM, GIS, and BI tools for university asset management	Case study	Optimized space and occupancy
Mane and Mhaske (2024)	BIM planning for time and cost optimization with power BI	Dashboard implementation	Cost and schedule optimization
Morato and Ferreira (2024)	VSM for loss and waste reduction in construction	Systematic literature review	Waste reduction benchmarks
Batwara et al. (2023)	Smart sustainable development through VSM	Bibliometric analysis; systematic review	Trends in VSM for sustainability
Gajera R. (2023)	BIM–Power BI integration for cost tracking	Case study	Budget variance reduction
Hammi et al. (2023)	Lean–BIM in the design phase for performance improvement	Experimental study	Design phase performance gains
Li et al. (2024)	NLP model for facility management in digital twins	Model development: Case study	Improved facilities data management
Roxo et al. (2022)	BIM with a BI tool for construction management	Case study	Enhanced project analytics
Michaud et al. (2019)	Lean approach to optimize BIM information flow	Value Stream Mapping; process analysis	Optimized information flow
Gunduz and Naser (2017)	Cost-based VSM for underground pipeline projects	VSM with cost analysis	Sustainable cost management
Ramalingam, S. (2018)	BIM process mapping for lean teaching	Conference proceedings	Improved BIM education methodologies
Patel et al. (2021)	VSM integrated with a foreman delay survey	Process improvement methodology	Reduced foreman delays
Zekhnini et al. (2022)	BIM–Power BI for data extraction and visualization	Photogrammetry archives implementation	Enhanced visualization and reporting

2025) and integrating BIM with game engines to improve stakeholder collaboration in order to overcome interoperability barriers (Rehman et al., 2025).

Ultimately, comprehensive systems that combine multiple digital tools with lean principles would reap the greatest benefits. Performance improvements have been reported in studies on Lean-BIM methodologies, particularly in the project design stage (Hammi et al., 2023). In a study by Jiang et al. (2024), BIM combined with QR-based tracking and future-state VSM showed a 12% increase in labor productivity and an 18% decrease in idle time. Higher-level conceptual models like coordination of BIM, IoT, and GIS could enable better resource management and collaborative decision-making (Liu et al., 2025). Some significant representative studies, their methods, and their outcomes are summarized in Table 1.

In summary, the existing studies have provided clear evidence that innovations like the BIM-to-BI pipeline allow for project status to become transparent so as to take proactive actions, and VSM can always be applied to effectively spot and remove non-value-adding steps. An integrated approach that combines lean, BIM, and other digital tools is said to be crucial in terms of narrowing the “big” divide between data analytics and managerial decisions. By operationalizing a full lean-digital loop that links VSM-based process enhancements with real-time BIM-to-Power BI dashboards and automated alerts, as well as by measuring its schedule impact on a large-scale institutional project in India, this study makes a useful, practical contribution.

3 Materials and methods

The study followed a two-pronged approach: (i) laying the base for the study’s methodology by reviewing the latest research in the domain of lean-digital integration and (ii) field-based interventions conducted using digital dashboards, VSM, and BIM supported by workflow automation.

An institutional building construction project was selected to apply VSM and measuring the changes to Value-Adding

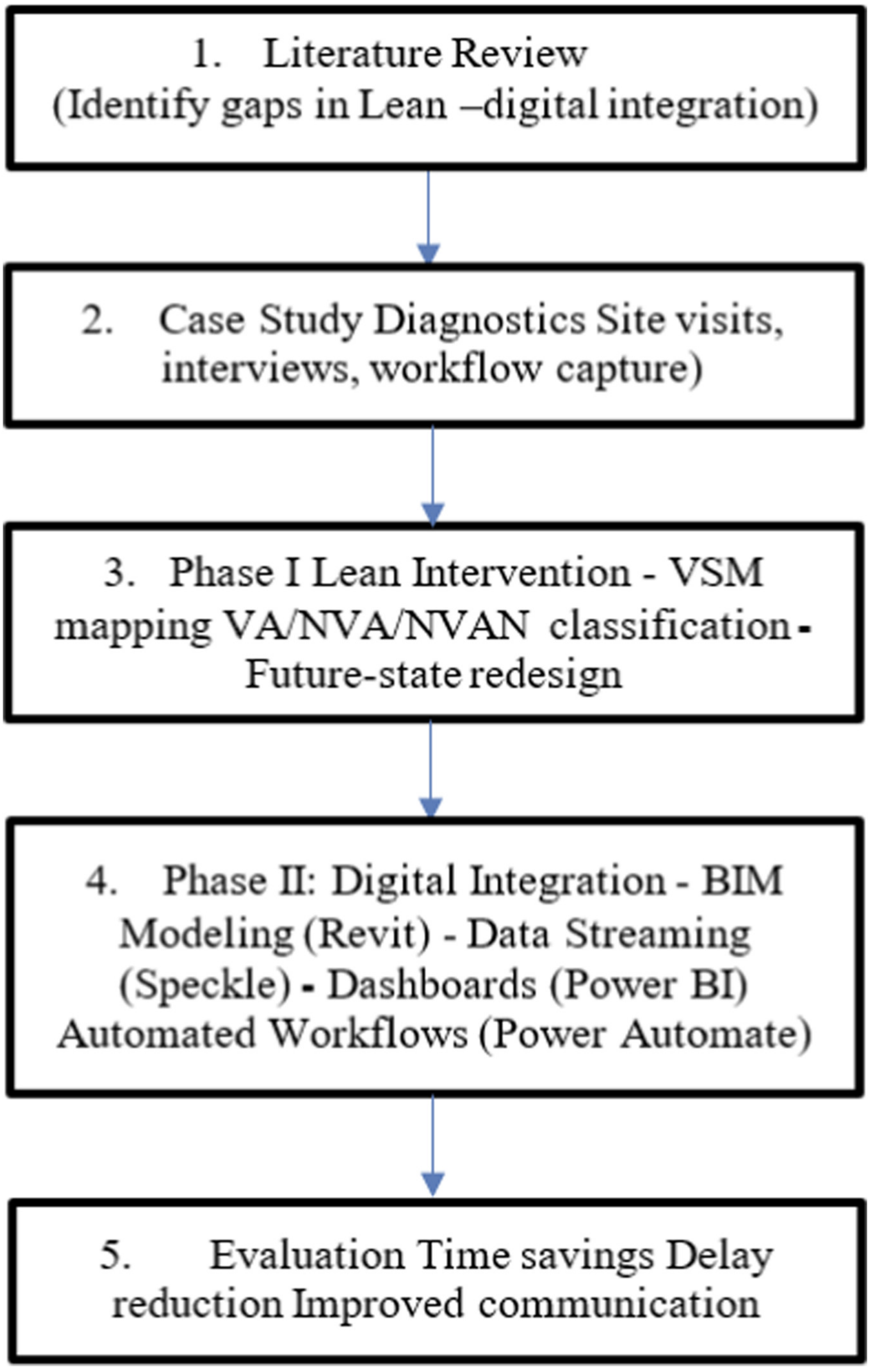


FIGURE 1
Research design.

(VA)/Non-Value Adding (NVA)/Non-Value Adding but Necessary (NVAN) activities, stream live BIM data via Speckle to Power BI, and automate alerts with Power Automate.

3.1 Literature-guided methodology

From the methodology perspective, the structure of the study approaches two streams of related literature: digital integration and lean construction. From studies, iterative VSM cycles involving workshops among stakeholders have been proved to systematically reduce project duration and eliminate non-value-adding activities (Morato and Ferreira, 2024). To show how VSM can help achieve the larger sustainability goals, it also has been extended by integrating environmental, social, and economic aspects (Batwara et al., 2023). Meanwhile, other investigators have emphasized team-level engagement and formatted VA/NVA/NVAN descriptions in a clear manner to enhance the clarity of workflow.

In the digital realm, Mane and Mhaske (2024) validated that BIM-to-Power BI dashboards can support real-time visibility of the metric at a 4D/5D project granularity level, increasing transparency and evidence-based decision-making. Di Giuda et al. (2024) created an interactive platform for facility management (FM) and further demonstrated the context of cyclic project events. Owais et al. (2024) deployed an automatic VSM system to gather data of machines from different sources so that the areas where it can be improved can be identified and digital twin was proposed as a method of enhancing VSM in terms of real time tracking and predictive analysis. Advanced integrations such as the open BIM-FM framework and the BIM game-engine provide for interoperability issues and ongoing data validation (Otranto et al., 2025; Rehman et al., 2025).

Case studies from the industry demonstrate the real-world effects of automation. For instance, Morgan Construction has integrated Power BI into employee onboarding to eliminate manual errors, and Downer New Zealand has integrated Flow Forma-Power Automate-GIS to automate 23 site processes, reducing administrative load and improving safety. The usefulness of BIM-IoT-GIS integration in resource management has also been reviewed (Liu et al., 2025), as has the creation of strategic roadmaps for digital twin construction management (Jiang et al., 2024). Together, these show that in order to completely address construction inefficiencies and produce quantifiable gains, lean process mapping must be integrated with real-time digital tools.

The existing body of work shows that inefficiencies cannot be overcome by lean or digital interventions in isolation. This also influenced the integrated approach adopted for the study, which combined real-time digital tools in Phase II with lean process mapping in Phase I to produce quantifiable efficiency benefits.

3.2 Research design and phases

The research was carried out in five stages, with reference to the design of work presented in Figure 1. The study started with a comprehensive review which articulated the holes in lean–digital integration. Secondly, to assess the baseline performance of the project case study diagnostics were applied using onsite visits, interviews with stakeholders and workflow capture. Third, to minimize waste and improve flow in Phase I (Lean Intervention), each task was classified as either VA, NVA or NVAN, current processes were mapped on ‘current state’ value stream diagrams, and future state redesigns with the site teams were initiated.

Fourth, a BIM model was generated in Autodesk Revit (central). For streaming the models live into Power BI dashboards for real time 4D/5D visualization, Speckle was used and Power Automate workflows were established to trigger automated alerts on task completion, approval or deviation. Finally, during the evaluation period, performance metrics including time saved, delays avoided and improvements to communication and decision-making with the integrated lean–digital intervention were triangulated.

3.2.1 Data collection and validation approach

The observations were obtained from a real time construction site in Vellore. Process flow, length of activities, delays and communication cycles were observed for 4 months on-site. Information was gathered from a variety of sources including site visits, MS Project schedule tracking, workflow mapping interviews, and documentation. Value-adding (VA), Non-value adding (NVA), and Non-value added but necessary (NVAN) elements were determined through site workflow analysis and then because of direct validation with the project manager.

MS Project was used for development of project schedule baseline and the revised schedules. Efficiency gains were assessed by comparing the duration of the baseline workflow with that of optimized workflow after Lean intervention. Efficiency of communication was also measured with RFI turnaround time labour and the average response time to any given question was approximately two working days under the protocol described.

3.3 Lean process mapping and iterative intervention

Value Stream Maps were produced for the operations of excavation, foundation, superstructure and finishing which are vital in construction process. With kanaka input and direct measurement, “Current state” maps revealed the amount of time spent in VA, NVAN and NVA activities. Collaborative workshops were facilitated to “future state” map, and match with project reality to prioritize actionable interventions. Validation through periodic mapping and process optimization improved results: 15% reduction in excavation time and total scheduling gain of at least 2.06%.

3.4 Digital platform integration

For the major work tasks including excavation, foundation, superstructure and finishing, Autodesk Revit would house the BIM models while Speckle allowed its bi-directional real-time data transfer to Power BI dashboards for reporting in dynamically visualized construction progress tracking information: material flow measurements as well as schedule keeping. Power Automate-enabled workflows notified in response to major turning points, deviations or approval requirements as they occurred in real time. In the dashboard space, row-level controls were implemented for security and privacy.

4 Implementation

The implementation strategy, which was carried out in two significant stages, combined digital innovation with lean methods:

Phase I: VSM-based lean construction optimization.

Phase II: Linking the real-time data from BIM and the model management platform Speckle to a Power BI dashboard for digital monitoring.

4.1 Phase I: lean methodology using VSM

Site clearance, excavations, foundation and trucking works were the main project activities that were mapped and classified as being

TABLE 2 VA/NVA/NVAN activities identification.

ID	Active	Name	Duration	Notes
1	Yes	Construction of institutional building	468 days	
2	Yes	Viv 2 project institutional building phase II	468 days	
3	Yes	Site possession to contractor	1 day	NVA
4	Yes	Survey point (R.L)	1 day	NVA
56	Yes	Institutional building (A BLOCK)	468 days	
57	Yes	Sub structure	180 days	
58	Yes	Excavation	67 days	
59	Yes	Site clearing	11 days	VA
60	Yes	Earth work excavation incl. Hard rock	56 days	VA
61	Yes	Foundation works	54 days	
62	Yes	Dressing the surface	54 days	VA
63	Yes	PCC	20 days	VA
64	Yes	Waterproofing works	25 days	VA
65	Yes	Foundation concrete	45 days	VA
66	Yes	Column and retaining wall upto basement floor	56 days	
67	Yes	Starter concrete	40 days	VA
68	Yes	RCC columns	40 days	VA
69	Yes	Retaining wall	40 days	VA
70	Yes	Back filling work-up to grade slab PCC bottom lvl	45 days	VA
71	Yes	Basement floor level	50 days	
72	Yes	PCC	35 days	VA
73	Yes	Reinforcement steel work	35 days	VA
74	Yes	Grade slab concrete works	45 days	VA
75	Yes	Basement roof slab	55 days	
76	Yes	Pour 1	28 days	
77	Yes	RCC column up to slab	10 days	VA
78	Yes	Slab shuttering work	18 Days	VA
79	Yes	Slab reinforcement work	16 days	VA
80	Yes	Electrical conducting	1 day	VA
81	Yes	RFI clearance	1 day	NVA
82	Yes	Slab concreting work	1 day	VA
83	Yes	Deshuttering	14 days	NVAN
84	Yes	Pour 2	28 days	
85	Yes	RCC columns up to slab	10 days	VA
86	Yes	Slab shuttering work –(incl staircase)	18 days	VA
87	Yes	Slab reinforcement work	16 days	VA
88	Yes	Electrical conducting	1 day	VA
89	Yes	RFI clearance	1 day	NVA

(Continued on following page)

TABLE 2 (*Continued*) VA/NVA/NVAN activities identification.

ID	Active	Name	Duration	Notes
90	Yes	Slab concreting work (including staircase)	1 day	VA
91	Yes	Deshuttering	14 days	NVAN
92	Yes	Pour 3	28 days	
93	Yes	RCC columns up to slab	10 days	VA
94	Yes	Slab shuttering work (including staircase)	18 days	VA
95	Yes	Slab reinforcement work	16 days	VA
96	Yes	Electrical conducting	1 day	VA
97	Yes	RFI clearance	1 day	NVA
98	Yes	Slab concreting work (including staircase)	1 day	VA
99	Yes	De shuttering	14 days	NVAN
100	Yes	Pour 4	28 days	
101	Yes	RCC columns up to slab	10 days	VA
102	Yes	Slab shuttering work	18 days	VA
103	Yes	Slab reinforcement work	16 days	VA
104	Yes	Electrical conducting	1 day	VA
105	Yes	RFI clearance	1 day	NVAN
106	Yes	Slab concreting work	1 day	VA
107	Yes	De shuttering	14 days	NVAN
108	Yes	Pour 5	28 days	
109	Yes	RCC columns up to slab	10 days	VA
110	Yes	Slab shuttering work (including staircase)	18 days	VA
111	Yes	Slab reinforcement work	16 days	VA
112	Yes	Electrical conducting	1 day	VA
113	Yes	RFI clearance	1 day	NVA
114	Yes	Slab concreting work (including staircase)	1 day	VA
115	Yes	De shuttering	14 days	NVAN

either necessary-but-non-value-adding (NVAN), non-value adding (NVA) or value-adding (VA) during the Lean optimisation exercise. The detailed break-up of the number of these tasks is shown in Table 2. To pinpoint waste sources and processing delays, particularly those caused by handoffs and approval cycles, this detailed categorization was done through structured interview, direct site observation, and review of project records.

Two types of VSM diagrams were created: the current state map, visualizing the present flow of activities and the future state map, indicating a sequence of steps for improvement in the future. As can be seen in Figure 2, the current state map identifies delays from several NVA components and the future state highlights ways of bundling activities (such as survey, mobilization, access-path preparation, and rock identification) to streamline the flow. The iterative process of coordination could help minimize avoidable delays under these findings. Consequently, the generated final schedule was enhanced for 2.06% and excavation duration as well as project delays decreased by 15% (234.88 h) compared to original schedule.

4.2 Phase II: digital integration dashboard, power BI, and speckle

The use of digital tools to enhance Lean construction principles is the key focus of the integration. The Institutional building project leveraged a seamless digital workflow focused on model optimization, data visualization and automation by utilizing state-of-the-art digital tools like Autodesk Revit, Speckle, Microsoft Power BI and Power Automate.

4.2.1 Revit modeling

Autodesk Revit platform was used as the primary digital modeling tool in this study. As shown in Figure 3, a detailed 3D

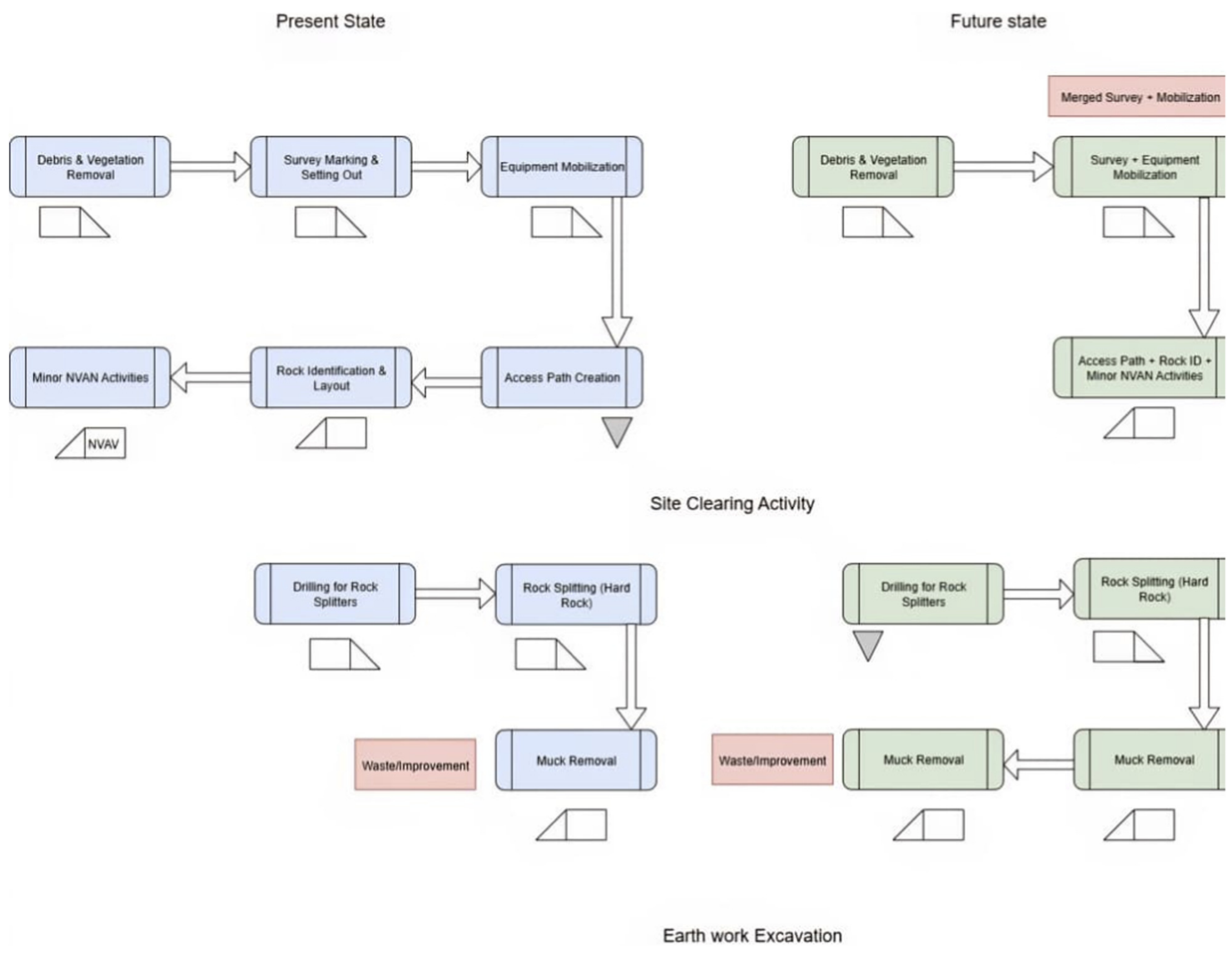


FIGURE 2
VSM diagram.

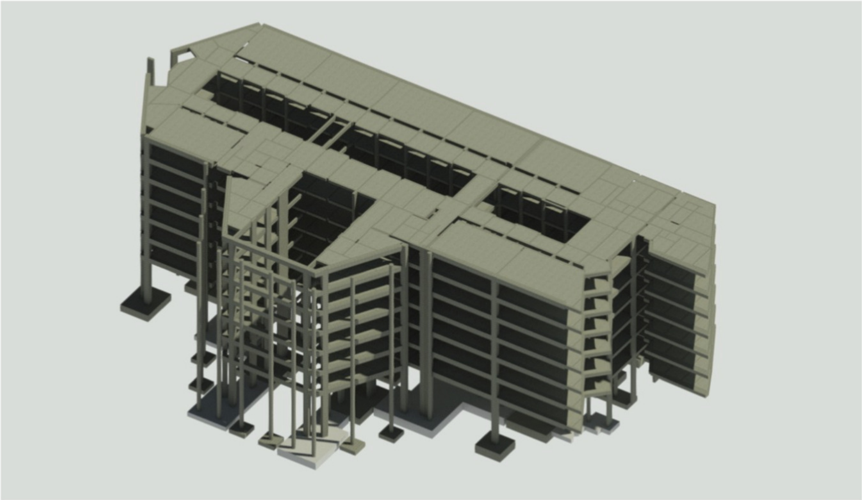


FIGURE 3
3D Revit model of the G+7 Institutional structure.

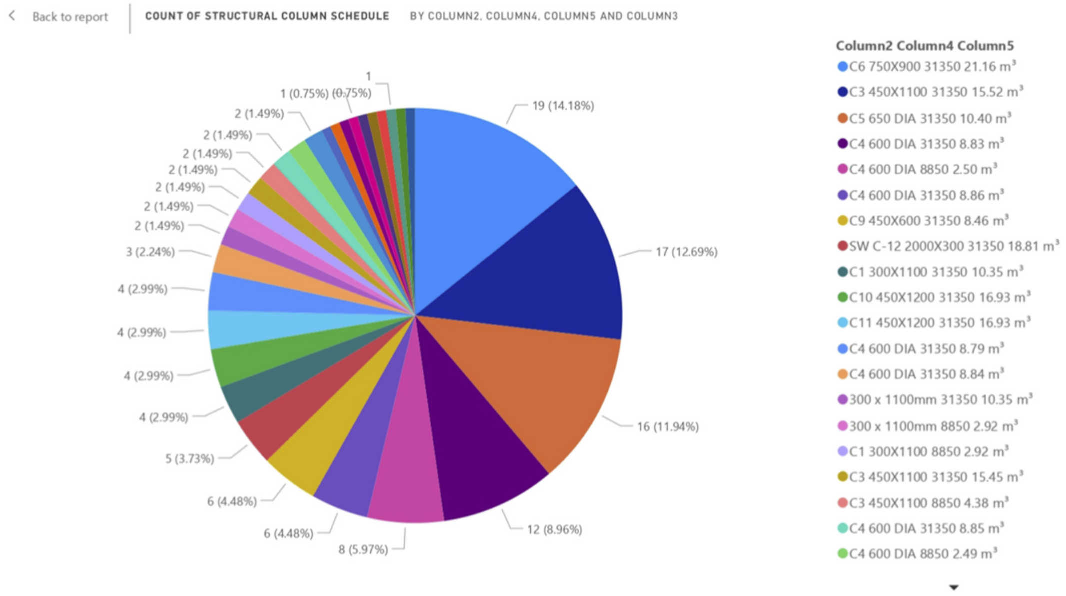


FIGURE 4
Power BI pie chart showing structural column distribution.

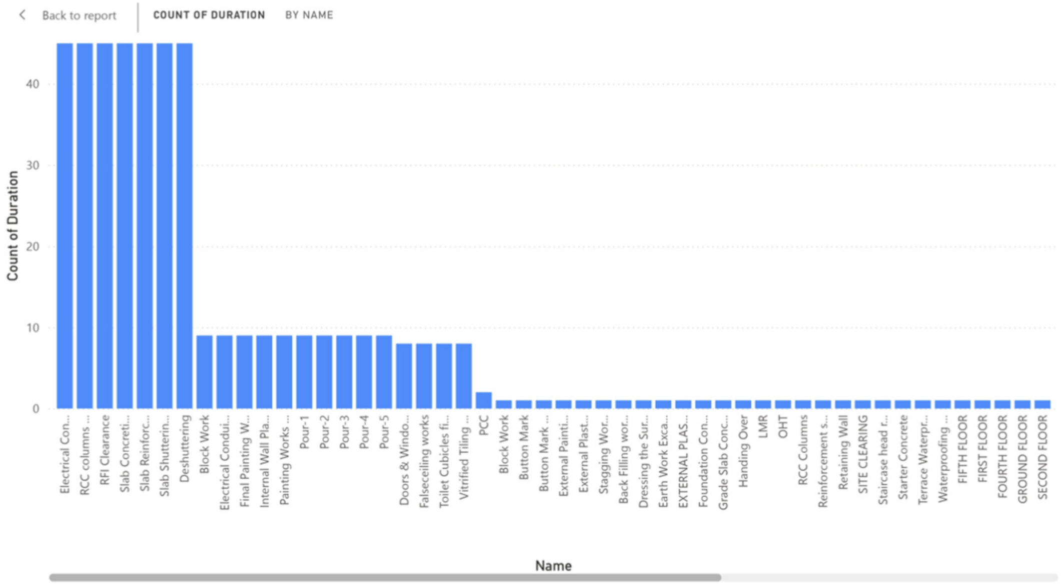
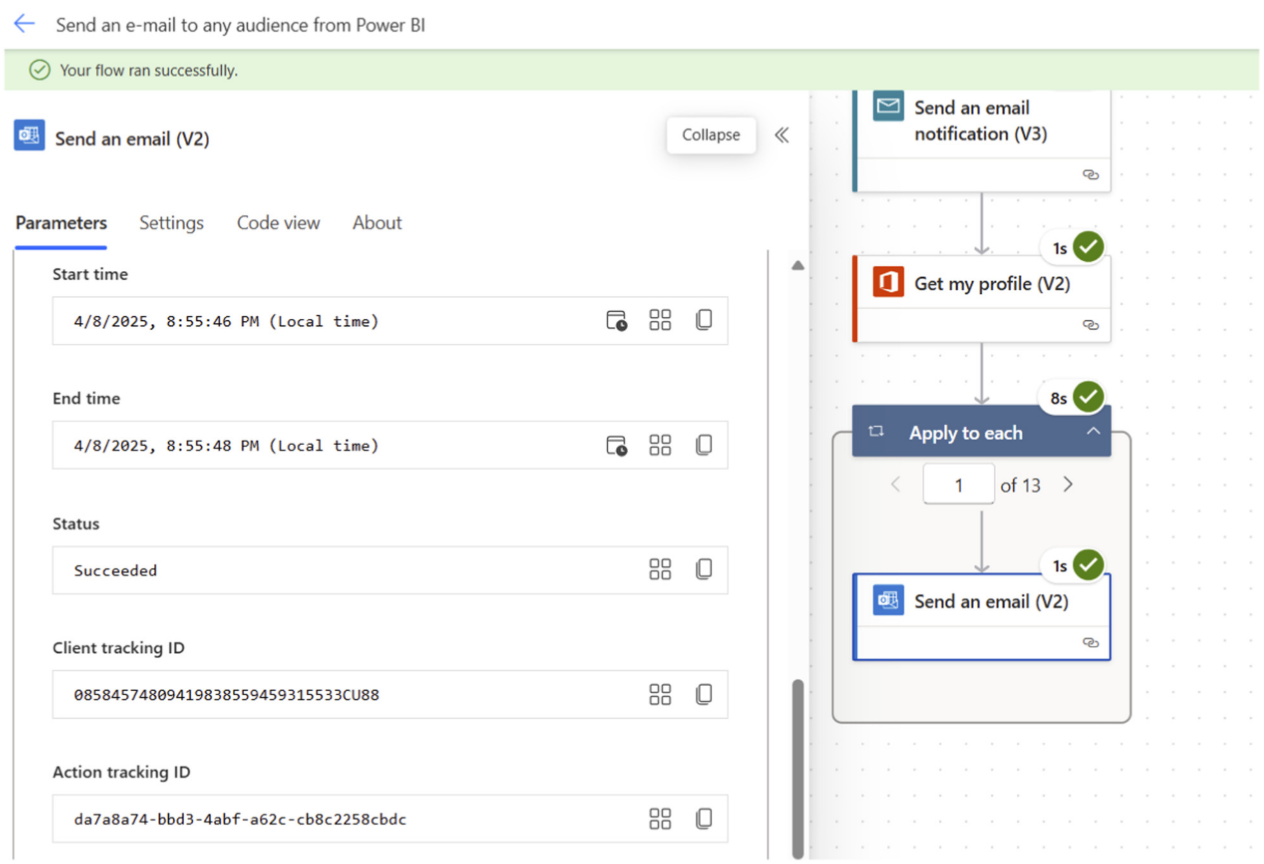


FIGURE 5
Activity duration visualization from the schedule analytics.

model of the institutional building located was developed with full parametric capabilities. To create a comprehensive digital model suitable for integration with Speckle, Power BI, and Power Automate, the model incorporated all major structural components, including columns, beams, footings, slabs, and the overall framing system.

Other than the part of visualization, the 3D model was used for the precise quantity takeoff. Quantities of structural elements were recovered seamlessly from the digital work flow (floors, beams, columns, framed steel systems), and it was also possible to determine an amount of reinforcement that would have to be used for modernization or renovation; as well as the total quantity of concrete that should have been ordered for the complete pouring. Each element in the model was an independent object that had properties including geometrical dimensions, material composition, and load bearing capacity as well as construction sequence. Such a rich model provided a vast amount of metadata which enabled standardized reporting and monitoring, better support



Your flow ran successfully.

Start time

4/8/2025, 8:55:46 PM (Local time)

End time

4/8/2025, 8:55:48 PM (Local time)

Status

Succeeded

Client tracking ID

08584574809419838559459315533CU88

Action tracking ID

da7a8a74-bbd3-4abf-a62c-cb8c2258cbdc

FIGURE 6
Power automate workflow successfully triggering email alerts.

for data-based decision making during any phase of the project. The project modeling was guided with the strictest of adherence to codes and standards and a very high calibration process that allowed us to represent field conditions as closely as possible to reduce any appearance of design discrepancy or ease of buildability. Built on the back of this, the construction execution was further streamlined using Revit's clash detection features which enabled spatial clashes to be quickly identified and resolved. The model's ability to replicate time-based progressions through integration with scheduling and phasing features enabled the virtual construction sequence to replicate real-world implementation and facilitate efficient project tracking.

An additional set of Revit families were created to meet the unique design needs of this Institutional facility. Project-centric parameters were integrated into these custom components, facilitating easy linkage with sophisticated dashboards and workflow automation frameworks, seamless integration with data extraction processes, and enhanced visual representation clarity. In summary, the digital tools not only enhanced the model utility and reliability but also showed its necessity for guide-level automation, correctness and efficiency of the project accomplishment.

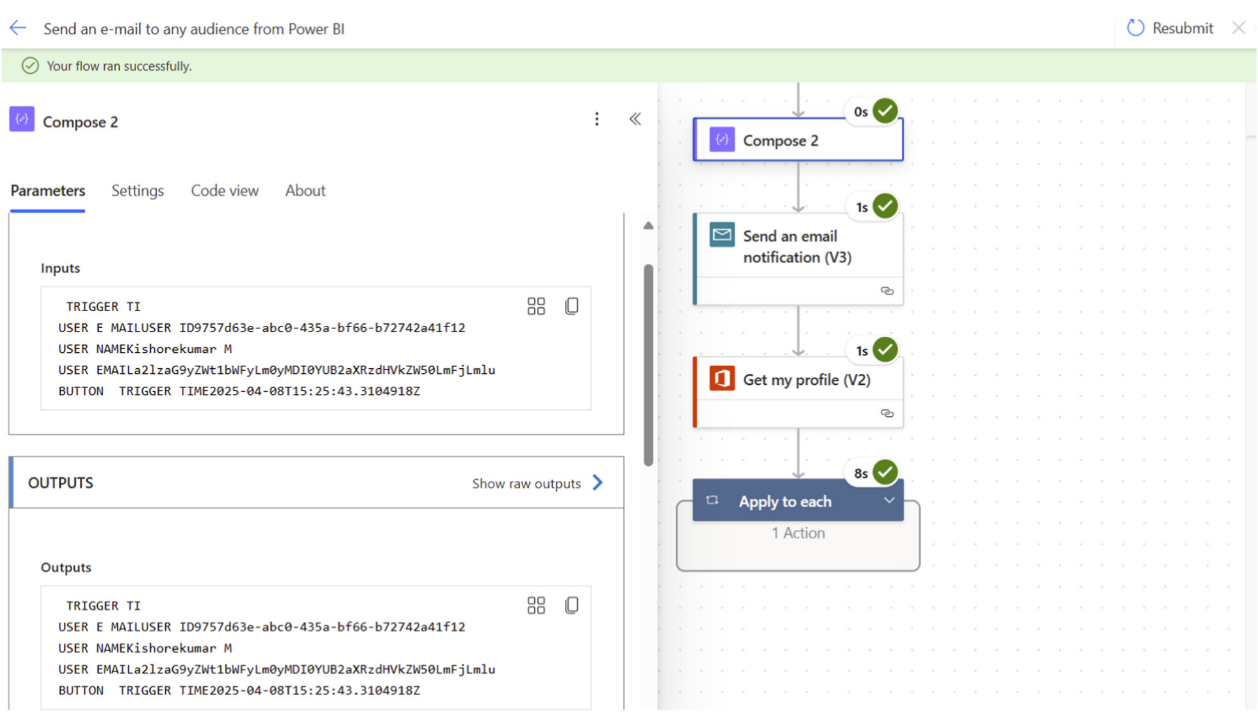
4.2.2 Speckle integration

An open-source, AEC data-exchange platform called Speckle was used to stream real-time data from Autodesk Revit to the downstream applications. Speckle's Directory API and Revit Connectors were configured to automatically transfer model data (including geometry, element type, construction phase/sequence, material status and component relations) to a central Speckle server. The system streamed continuous data between Revit and the analytical platforms including Power Automate, Power BI and other supported application to automatically show the changes to the model as soon as they are made. It also facilitated decision-making, reporting of timely information and data-driven construction management.

Speckle transfers the design output from one tool into another for further analysis needed. It allows to store all previous model changes, references and, if required, forensically visit design differences or progression. Furthermore, Speckle enables multiple discipline teams such as architectural, structural and MEP to stream the discipline specific models into the single digital environment with federated models. It facilitates inter-discipline coordination and also helps to prevent, at an early stage of project design, clashes or even inconsistency. It ensures important information about a project can be accessed as and when needed, while supporting the collaboration process.

4.2.3 Power BI dashboard development

An interactive dashboard for the project was created in Microsoft Power BI. Real-time interactive construction



Send an e-mail to any audience from Power BI

Your flow ran successfully.

Inputs

```
 TRIGGER TI
USER E MAILUSER ID9757d63e-abc0-435a-bf66-b72742a41f12
USER NAMEKishorekumar M
USER EMAILa2lzaG9yZWt1bWFyLm0yMDI0YUB2aXRzdHVkZW50LmFjLmlu
BUTTON  TRIGGER TIME2025-04-08T15:25:43.3104918Z
```

Outputs

```
 TRIGGER TI
USER E MAILUSER ID9757d63e-abc0-435a-bf66-b72742a41f12
USER NAMEKishorekumar M
USER EMAILa2lzaG9yZWt1bWFyLm0yMDI0YUB2aXRzdHVkZW50LmFjLmlu
BUTTON  TRIGGER TIME2025-04-08T15:25:43.3104918Z
```

FIGURE 7
Power automate flow details with timestamp and user trigger.

analytics were carried out based on the model data from Autodesk Revit that is continually synchronised via Speckle streams and visualised natively in the dashboard. Figures 4, 5, represent sample data from the dashboard showing the distribution of structural components and activity duration information through live visualization. The dashboard proved to be a seamless interface to navigate between construction progress, material reuse, quantities for demolition and structural components' current position in the fabrication cycle. All the construction levels were able to be seen, while having appropriate filters like floors and structure elements (beams, columns or slabs) stages of construction. This provided on-the-fly visibility to construction taks like reinforcement needs/progress/status, inspections and concrete take-offs for each in-place location compared to project plan.

Non-technical users as well as construction professionals alike could effortlessly interpret the project data through the visualizations including bar charts, heatmaps, and Key Performance Indicator (KPI) updates. One of the significant additions to this technology integration was the use of natural language processing (NLP) based chat option in the dashboard. For instance, users could ask: "Show me all completed beams on Level 5" and see the response directly. It consolidated Excel and Microsoft Project schedule data, in order to see and compare baseline plans versus real time progress at once. This made it easy to determine resource bottlenecks, critical path delays and slippage.

Continuous syncing with the live Speckle updates enabled the automatic capture of any changes to the Revit model, be it design changes, metadata or otherwise. This also helped in fast decision making by removing the manual refreshes that were required to update the project status. The system had row-level security protocols to ensure that the different stakeholders like project managers, site engineers and clients were able to access only the data relevant to them (i.e., it locked down firm data while enabling collaboration) so that the admininstrative and privacy standards were ensured.

4.2.4 Power automate service

The digital workflow for managing the project using Microsoft Power Automate tool resulted in reduced manual tracking and reporting. As shown in Figures 6, 7 below, Power Automate was able to read live metadata from the Revit–Speckle environment and send automated email notifications, workflow actions, and condition-based alerts. This helped in achieving tighter communication loops, enhanced responsiveness and event-driven coordination between the project teams. Another important automation solution used was getting real-time update alerts of the construction progress in the BIM environment. The moment when an element was updated from "In Progress" to "Completed", Power Automate would send a notification to the site engineer and quality control team to facilitate same-day inspections and clearance. Furthermore, predictive notifications were sent in case of any delay was being anticipated to any of the project tasks, based on the input data from progress updates and changes inflicted. This gave the project team the ability to take a preventive action to control delays, deploy extra resources and plan recovery actions with the aim of reducing schedule deviations.

TABLE 3 Time optimization using VSM.

Activity	Total duration before applying lean principles (hr.)	Total duration after applying lean principles (hr.)	Percentage of reduction
Substructure			
Excavation	536	455.6	15
Foundation work	432	419.08	3
Column and retaining wall up to basement floor	448	448	0
Basement floor level	400	400	0
Basement roof slab	440	435.6	1
Superstructure			
Ground floor roof slab	408	403.92	1
First floor roof slab	352	348.48	1
Second floor roof slab	352	348.48	1
Third floor roof slab	352	348.48	1
Fourth floor roof slab	352	348.48	1
Fifth floor roof slab	352	348.48	1
Sixth floor roof slab	352	348.48	1
Terrace floor roof slab	352	348.48	1
Above terrace	360	360	0
Architectural finishes			
Basement floor	480	473.28	1.4
Ground floor	640	631.04	1.4
First floor	640	631.04	1.4
Third floor	640	631.04	1.4
Fourth floor	640	631.04	1.4
Fifth floor	640	631.04	1.4
Sixth floor	640	631.04	1.4
Seventh floor	640	631.04	1.4
External works	592	552	6.7
Terrace waterproofing	360	360	0
Total duration	11400	11165.12	
% of saved time	2.06%		

Additionally, third party tools like SharePoint were used to collate the uploaded documents like BIM model inspector reports and Requests For Inspection (RFIs) in pre-designated project folders, in accordance with document control protocols. The project members were added to Microsoft Teams where queries could be posted in channels dedicated to site engineers and planners who required live updates. Through the integrated tools, the critical path was matched with the time-based resource demands, thus resulting in lesser risk of cascading delays. Overall, the integration of Power Automate made the project tracking and communication to become self-monitoring and digitally responsive.

5 Results and discussion

Like many other projects, the selected institutional building construction also faced several chronic problems such as weather-related delays, supply chain and design unpredictability, and shifting labor availability, which had contributed to the production inefficiencies and overruns. To assess the current state of the project, it was decided to map the value streams for each of the main processes involved in the execution work. This was achieved with the aid of site diaries, resource logs and visual observation, and activities were classified

TABLE 4 Summary of Key Performance Indicators (KPIs) observed during implementation.

KPI	Observation/Result	Evidence source
Project location	Vellore	Site execution records
Monitoring duration	4 months	Site monitoring and observations
Schedule planning tool	MS project	Baseline and revised schedules
VA/NVA/NVAN classification validation	Verified with project manager	Workflow review discussions
Excavation activity improvement	15% reduction in duration	VSM time comparison
Overall project time improvement	2.06% reduction in total duration	Schedule comparison analysis
RFI response time	Approximately 2 working days	Site communication tracking

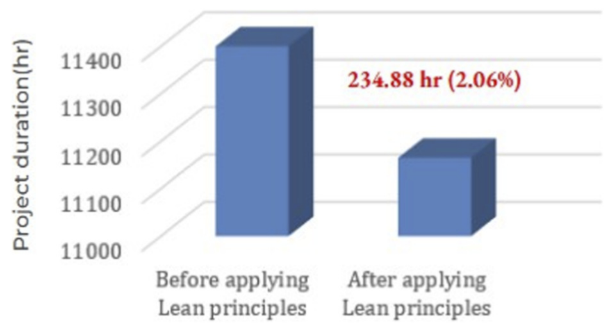


FIGURE 8
The Effect of Lean (VSM) on the construction activity duration of Institutional Building.

as non-value adding work, non-value-adding or value-adding. These were communicated to the project team and efforts were taken to eliminate all the non-value adding activities based on the future state map. Once the project activities were streamlined, there was significant reduction of time observed. Table 3 shows the details of activities and their respective durations before and after lean implementation through VSM.

Key performance indicators (KPIs) reported based on the actual execution of the Lean–Digital. Table 4 summarizes those KPIs. An analysis was conducted at a live construction site in Vellore and observed for 4 months. The project time-schedule in MS Project and the effect of improvements were assessed by baselined versus real durations after Lean interventions. The categorization of activities VA, NVA, and NVAN was evaluated through confirmation by the project manager to confirm accuracy of workflow analysis. The implementation results indicate quantifiable enhancements, such as 15% in duration of excavation activity and 2.06% project time reduction. Furthermore, the project communication effectiveness was tracked by RFI response time which found that it was about two working days under the current system.

In order to better continuous supervision and decision-making, these KPIs were also visually processed into this real-time visualization flow through data extraction from BIM model and dashboard intergration. The project model and its datasets were kept in synch using Speckle, ensuring updated project information flowed into a centralised reporting system. Power BI dashboards were subsequently created to monitor workflow status, progress and key performance indicators in an accessible manner. This included integrating the VSM with digital dashboards to ensure that lean improvements generated were not just observed but also measured dynamically, enabling the project team to more fully check in on progress quicker and address things like TSIs approvals and RFIs sooner.

Through the elimination of redundant handoffs and waits in the excavation stage, activity time was reduced from 536 h to 455.6 h - a reduction of 15%. With accelerated approval processes and efficienct sequencing, the project gained further efficiencies of 1.4%–3% in the foundation and slab operations as well. In total, these changes decreased the length of project time by 234.88 h (i.e., 2.06% shortening from 11400 h down to 11156.12). The detailed breakdown of these improvements is presented in Table 3. Delays in drawing approvals, needless motion, ineffective material transportation, and avoidable workflow stoppages were the main waste categories that were addressed during this study. Figure 8 provides a comparison of overall project duration before and after applying lean principles.

Further improvements were achieved by the adoption of digital technologies after VSM implementation. As shown in Figure 9, a real-time feedback loop was introduced demonstrating progress, resource utilization and new workflow concerns via a live Power BI dashboard updated on the fly from Revit models (BIMs) through the Speckle platform. This data pipeline provided instantaneous, automatic information in place of time consuming manual updates. Closing feedback loops was another important function of Power Automate, which produced instant alerts of any schedule or model deviations, as seen in Figure 10, so that the execution and project management teams could react proactively as opposed to reactively. As the digital system evolved, the team members got more clarity in their daily responsibilities, reporting cycles and decision-making timelines shrank, and data input mistakes decreased.

The benefits of lean and technological integration in the project were only attained following a continuous investment in team training and a committed cultural shift toward data-driven management. Early challenges, such the transition to new sequences, matching real-world progress with model data, were similar to those encountered by many other construction projects which need continuous improvement and feedback. The limitations of process and technology are demonstrated by the fact that other external vulnerabilities, such as labor availability and climate impacts, can still control the project outcomes. By taking excavation as a sample activity, Figure 11 shows an activity level

FIGURE 9
Power BI Dashboard with structural insights and schedule integration.

vs. project level savings in duration where as, Figure 12 shows the improvement in other qualitative parameters like stakeholder response, and report/data turn around time) as well as the reduction in approval lags.

Together with the usual benefits extracted from literature (construction uses of VSM often reducing between 10%–30% the cycle time, associated to wait for approval flows, material flow or idle times (Morato and Ferreira, 2024), The use of the lean tool VSM combined with digital technologies like BIM (Revit) BI (Power BI) and automated work (speckle), led to making a 15% reduction in duration on excavation tasks which were a vital contribution to obtain an overall saving time of 2.06% in project delivery esacpement standards. Instantaneous decision making is another important impact of the automatic alerts and live dashboards (on project control) also reflecting evidence based documentation on the productivity and time/cost visibility outcomes from BIM-BI where as much as 25% improvement attainment has been registered in real-time decision support, as well as acceleration process optimization (Mane and Mhaske, 2024; Gajera, 2023; Di Giuda et al., 2024). International benchmarking also suggest that lean–digital paradigms tend to global cut programs by 2%–15% depending upon project size and digital maturity (Hammi et al., 2023; Owais et al., 2024). Similarly, systematic waste identification and VSM-driven improvements have been found to achieve physical benefits in labour productivity gains (e.g., as much as a 12% increase in productivity and 18% reduction of idle time) using digital twin-enabled VSM case study (Jiang et al., 2024). Nonetheless, literature also reports several practical barriers associated with the adoption of digitalized construction ecosystems, such as budget constraints, data security problems, regulatory obstacles, and lack of coordination between IT managers and operations team due to limited interoperability and workforce resistance (Rehman et al., 2025; Otranto et al., 2025). Furthermore, numerous researches highlight that digitalization cannot completely mitigate external disturbances such as negative weather conditions or supply chain instability and resource constraints which still constitute major sources of variability for building projects (Liu et al., 2025; Jiang et al., 2024).

The key inferences from this study are, real-time data flows are key to a successful lean journey along with structured change management, continuous training and leadership support. Early quick wins can break the ice on resistance. Apart from continuing the longitudinal validation with different projects and increasing scalability and robustness, future developments might involve new technologies like IoT, Digital Twins, AI based analytics and so on.

6 Theoretical and practical implications

The theoritical contribution of this study to lean construction research is that, it demonstrates how a lean tool combined with integrated digital tools (BIM, Power BI and Speckle) can achieve solid efficiency improvements.

6.1 Proposed lean–digital integration framework

Besides the actual time-saving realized, it was observed that qualitative improvements had been achieved by applying the proposed Lean–Digital integration framework in terms of

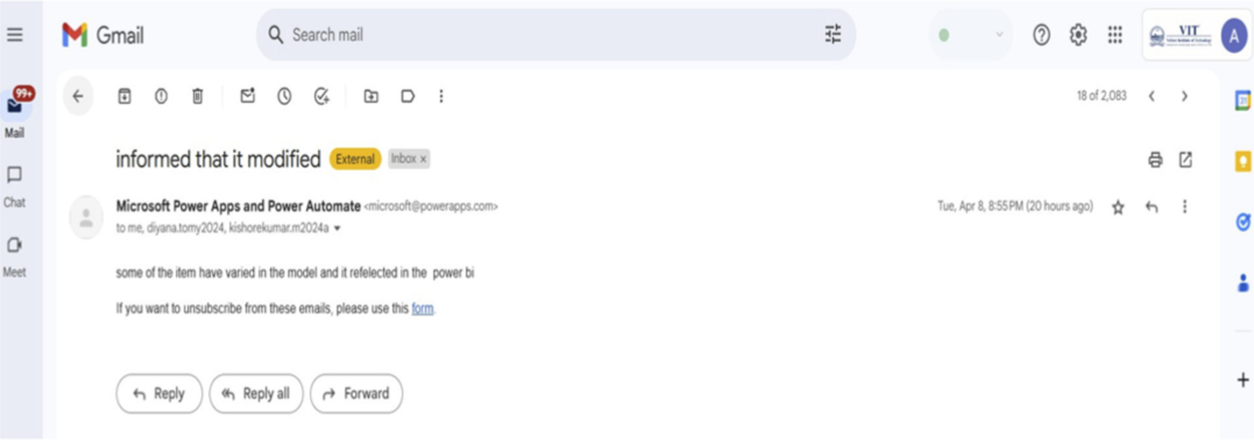


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FIGURE 10
Automated Email generated via Power Automate and successfully received in the inbox.

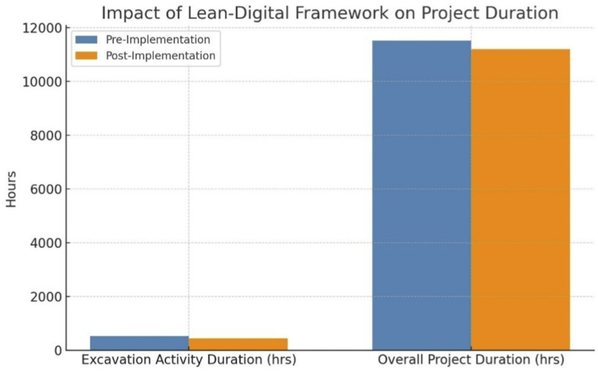

FIGURE 11
Impact of the lean–digital framework on project duration.

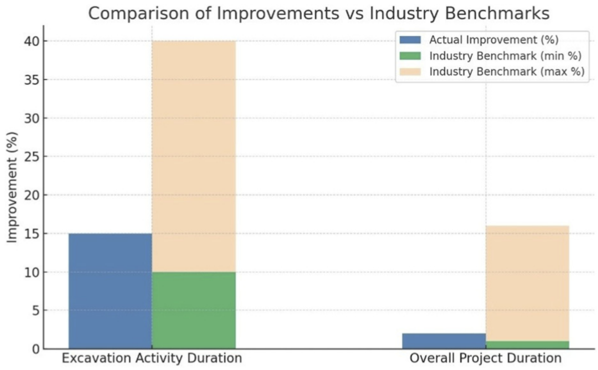

FIGURE 12
Comparison of actual improvements with industry benchmarks.

improved communications with stakeholders, greater transparency, expedited approval cycles and more efficient coordination among project teams. We summarize the overall quantitative effects of the framework in Figure 13.

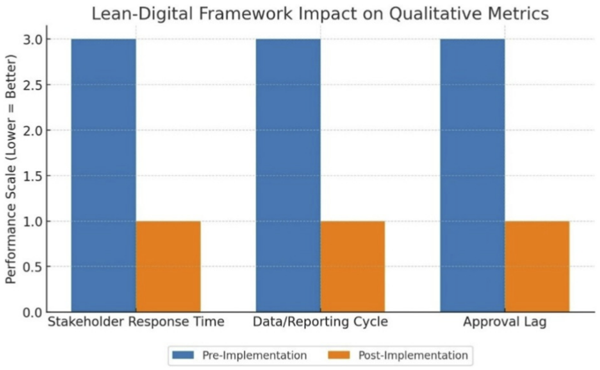

FIGURE 13
Lean-digital framework impact on qualitative metrics.

The study proposes a practical Lean–Digital integration framework for planning and site level execution which is represented in Figure 14. The framework is proposed to enhance the construction productivity using process optimisation and real-time monitoring. This framework is divided into two main stages: (i) Planning Phase (Pre-construction) and (ii) Implementation Phase (Site implementation). Inputs to the project are gathered and a Value Stream Map (VSM) is created for the current state based on this definition into VA, NVA, and NVAN categories. Bottlenecks are identified, and a future state VSM is created to improve the process. Streamline data synchronization and monitoring with BIM development and digital system configuration in Speckle, Power BI, and Power Automate. In the execution phase, the modified lean plan is executed in a field office or site and updated with progress data and RFI information at regular intervals while real-time KPIs are monitored using dashboards. Automated notifications facilitate the timely decision making, followed by control actions and the improvement loop for eternal refinements of project strategy.

The recommended lean-digital integration framework provides practitioners an empirical roadmap for transforming the integrated project delivery. The creation of real-time digital dashboards could

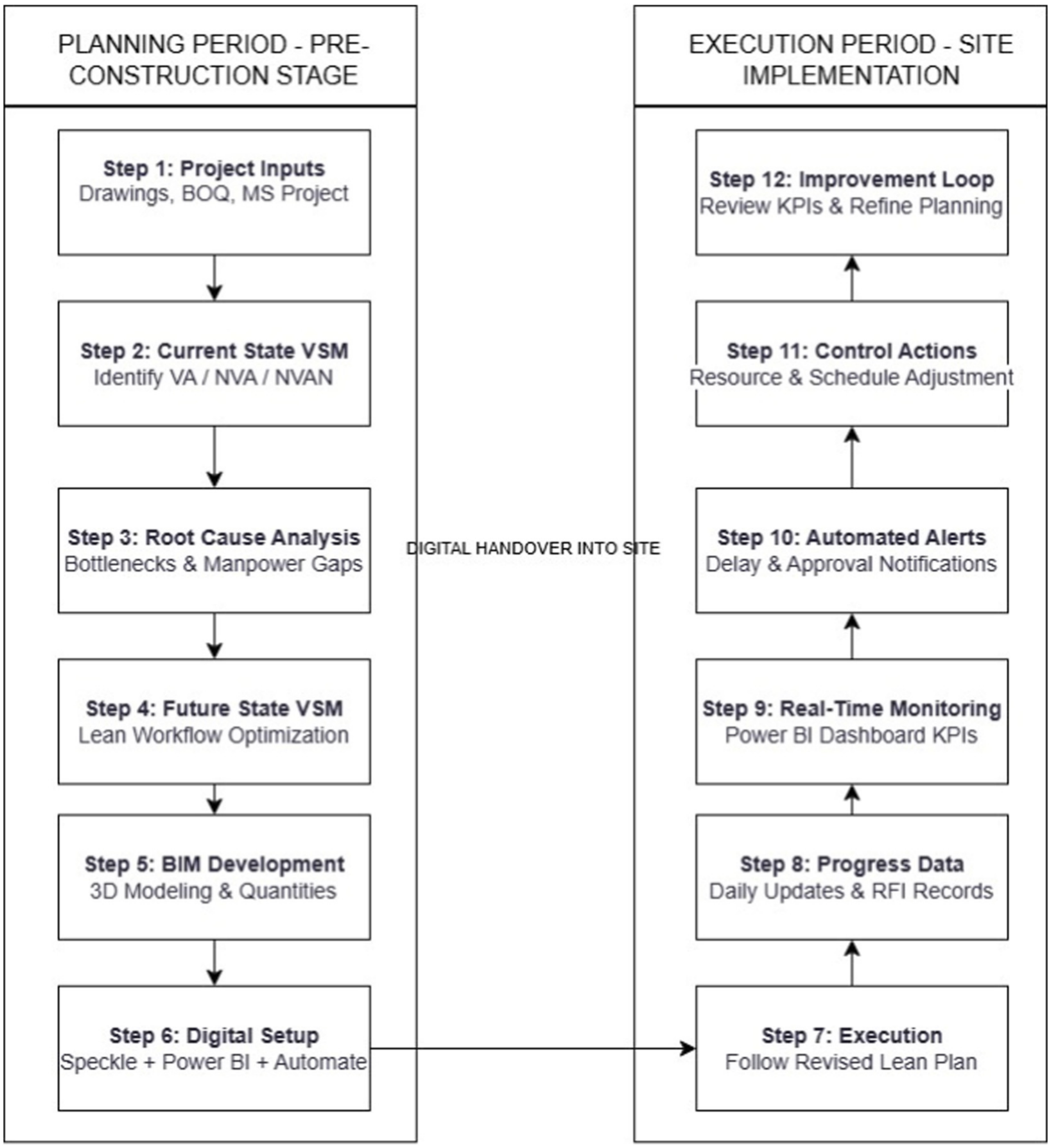

FIGURE 14
Practical lean–digital integration framework for planning and site execution.

reduce the cycles of manual reporting greatly, allowing teams to make faster decisions. Adopting open data exchange platforms like Speckle can improve coordination by easing the integration of multi-disciplinary stakeholders. The study provides a roadmap for clear change management, to achieve early “quick wins”, which is designed and backed by leadership, and sharp training to deal with resistance in this phase.

7 Conclusion

The results of this research showed that digital technologies like BIM, BI and automated data exchange can be seamlessly integrated with lean practices and bring considerable improvement in project delivery time of construction. VSM allowed for time savings, in a selected excavation activity around 15% which accounted for about 2.06% reduction in overall project time.

Through real time digital connectivity, everyone in the value chain from site managers and engineers–could see the progress at a glance, get instantaneous updates on model changes or hazards to schedule and act on issues far quicker than with traditional reporting. In addition to the ability for faster review and feedback, accessible data also helps teams collaborate more effectively, hold each other accountable more efficiently and enables faster decision making. With constant visibility and automatic notifications, perceived benefits like better role clarity and ownership can be gained. The case also demonstrated the significance of feedback hardwire support and customization.

The results of this study can be viewed in the context that a scaleable lean-digital integration may not only increase the performance of individual projects, but also could help in creating a consistent pattern in the construction industry.

All of these need to be further underpinned and developed through greater investment in digital infrastructure, training team members and creating an iterative approach towards process improvements. The benefits for practice will help to support the wider industry move towards complete lean and digital adoption resulting in more efficient, transparent projects that are competitive globally over the long term.

7.1 Limitations and recommendations

The study considered only a selected activity for analysing the impact of lean integration with digital technology and extrapolated it to the project level outcomes. Moreover the study did not consider the detailed impact of other types of lean wastes and micro-level productivity details. The solutions recommended are based on empirical data from an example project site whereas the conditions and processes can vary in other projects. The cost-benefit analysis of adapting the technologies was not considered as well, which can be explored in future studies.

The emergence of other Industry 4.0 technologies like Internet of Things (IoT), Digital Twins, Automated Robots, and Artificial Intelligence is having a significant impact in the construction industry. The exact impact and benefits of such technologies and their synergy with lean needs a thorough research investigation. It is also needed to establish industry standards and best practices which will drive the ongoing progress across the entire building sector.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

KM: Conceptualization, Methodology, Software, Formal Analysis, Investigation, Data curation, Visualization, Writing – original draft. DT: Investigation, Data curation, Validation, Writing – review and editing. AV: Formal Analysis, Validation, Writing – review and editing. PR: Supervision, Conceptualization, Methodology, Writing – review and editing. BA: Validation, Writing – review and editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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References

Abdelghany, S., and Shokri, S. (2021). Using BIM as a lean management tool in construction processes – a case study. *HBRC J.* 17 (1), 60–73. doi:10.1080/16874048.2021.1963032

Abedini, A., Nik-Bakht, M., Asnafi, B., and Ghafari, M. (2021). Lean practices using building information modeling (BIM) and digital twinning for sustainable construction. *Sustainability* 13 (1), 161. doi:10.3390/su13010161

Aliakbar, A., Ardeshir, A., and Ahmad, S. (2024). From building information modeling to construction digital twin: a conceptual framework. *J. Inf. Technol. Constr.* 29 (3), 512–530. doi:10.1080/21693277.2024.2387679

Batwara, A., Sharma, V., Makkar, M., and Giallanza, A. (2023). Towards smart sustainable development through value stream mapping: a systematic literature review with bibliometric analysis. *Heliyon* 9 (5), e15852. doi:10.1016/j.heliyon.2023.e15852

Di Giuda, G. M., Meschini, S., Gasbarri, P., Accardo, D., Tagliabue, L. C., and Cacciaguerra, E. (2024). BIM, GIS and BI tools for a university asset management system supporting space management, occupancy evaluation and optimization strategies. *J. Inf. Technol. Constr.* 29 (5), 1128–1155. doi:10.36680/j.itcon.2024.050

Gajera, R. (2023). Integrating power BI with project control systems: enhancing real-time cost tracking and visualization in construction. *Int. J. Sci. Res. Civ. Eng.* 7 (6), 45–52. doi:10.32628/IJSRCE123761

Gunduz, M., and Naser, A. F. (2017). Cost based value stream mapping as a sustainable construction tool for underground pipeline construction projects. *Sustainability* 9 (12), 2184. doi:10.3390/su9122184

Hammi, F., Messaoudi, A., and Loukil, S. (2023). Lean-BIM approach for improving the performance of a construction project in the design phase. *Buildings* 13 (3), 654. doi:10.3390/buildings13030654

Jiang, Y., Su, S., Zhao, S., Zhong, R. Y., Qiu, W., Skibniewski, M. J., et al. (2024). Digital twin-enabled synchronized construction management: a roadmap from construction 4.0 towards future prospect. *Dev. Built Environ.* 19, 100512. doi:10.1016/j.dibe.2024.100512

Li, X., Wu, X., and Liu, Q. (2024). Towards digital-twin-enabled facility management: the natural language processing model for managing facilities in buildings. *J. Inf. Technol. Constr.* 29 (2), 235–251. doi:10.1080/17508975.2024.2370372

Liu, X., Antwi-Afari, M. F., Li, J., Zhang, Y., and Manu, P. (2025). BIM, IoT, and GIS integration in construction resource monitoring. *Automation Constr.* 174, 106149. doi:10.1016/j.autcon.2025.106149

Mane, P., and Mhaske, S. (2024). BIM-Based planning for time and cost optimization with power BI. *Smart Eng. J.* 5 (2), 101–110. doi:10.70729/SE24616165414

Michaud, M., Forgues, E. C., Carignan, V., Forgues, D., and Ouellet-Plamondon, C. (2019). A lean approach to optimize BIM information flow using value stream mapping. *A Lean Approach Optimize BIM Information Flow Using Value Stream Mapping. J. Inf. Technol. Constr.* 24, 472–488. doi:10.36680/j.itcon.2019.025

Morato, M. L. D. S., and Ferreira, K. A. (2024). "Value stream mapping application for construction industry loss and waste reduction: a systematic literature review," in *International Journal of Lean Six Sigma* (Bingley, United Kingdom: Emerald Publishing Limited), 15, 817–837. doi:10.1108/ijlss-06-2023-0100

Newhouse, B., Souppaya, M., Cooper, D., Polk, T., Barker, W., Scarfone, K., et al. (2025). "Addressing visibility challenges with TLS 1.3 within the enterprise: high-Level document," in *NIST Special Publication*. Gaithersburg, MD: National Institute of Standards and Technology (NIST), 1800–1837. doi:10.6028/NIST.SP.180037

Otranto, R. B., Junior, G. M., and Pellanda, P. C. (2025). BIM–FM integration through openBIM: solutions for interoperability towards efficient operations. *J. Inf. Technol. Constr.* 30 (12), 298–318. doi:10.36680/j.itcon.2025.012

Owais, O. A., Poshdar, M., Bidhendi, A., Jaafar, K., and Sarhan, S. (2024). "From concept to concrete: Digital twins enabling different levels of lean construction," in *Proceedings of the 32nd annual conference of the international group for lean construction (IGLC 32)*, 767–779. doi:10.24928/2024/0206

Patel, S., Mistry, D., and Shah, M. (2021). A process improvement methodology for effective implementation of value stream mapping integrated with foreman delay survey. *Innov. Infrastruct. Solutions* 6 (3), 137. doi:10.1007/s41062-021-00512-1

Ramalingam, S. (2018). "Mapping of BIM process for teaching lean," in *Proceedings of the 26th annual conference of the international group for lean construction*, 1291–1301. doi:10.24928/2018/0258

Ramani, P. V., and Lingan, L. K. (2019). Developing a lean model to reduce the design process cost of gas insulated switchgear foundation using value stream mapping – a case study. *Int. J. Constr. Manag.* 22 (4), 669–677. doi:10.1080/15623599.2019.1644756

Rehman, S. U., Kim, I., and Hwang, K. E. (2025). Advancing BIM and game engine integration in the AEC industry: innovations, challenges, and future directions. *J. Comput. Des. Eng.* 12 (4), 26–54. doi:10.1093/jcde/qwaf030

Roxo, P., Gouveia, V., and Leitão, A. (2022). Construction management supported by BIM and a business intelligence tool. *Energies* 15 (9), 3412. doi:10.3390/en15093412

Zekhnini, H., El Kadiri, K., Benabbou, K., and Chehab, N. (2022). An integrated BIM-power BI approach for data extraction and visualization. *Int. Archives Photogrammetry, Remote Sens. Spatial Inf. Sci.*, 67–74. doi:10.5194/isprs-archives-XLVIII-4-W4-2022-67-2022