VALUE STREAM MAPPING FOR LEAN CONSTRUCTION WASTE IDENTIFICATION IN PRECAST FAÇADE INSTALLATION: A HIGH-RISE APARTMENT CASE STUDY

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ABSTRACT

Precast façade systems are increasingly used in high-rise construction, but their effectiveness depends on the synchronization of material delivery, lifting, work-front readiness, and installation activities. This study aims to identify construction waste and workflow inefficiencies in precast façade installation using a macro-level Value Stream Mapping (VSM) approach. A quantitative descriptive case study was conducted on a high-rise apartment project in Jakarta, Indonesia, involving 33 construction professionals. Data were collected through structured questionnaires, site observations, and project documentation. The results show that 258 of 523 planned façade panels were installed, representing an overall achievement of 49.33%, while the mean achievement across Floors 8–12 was 50.70%. Waiting and inventory were the most dominant wastes, both with a mean score of 4.42, followed by overproduction and overprocessing with scores of 4.36. The macro-level VSM indicates that these wastes are associated with synchronization problems among material delivery, temporary storage, lifting availability, and installation readiness. A Future-State VSM is therefore proposed based on pull-based material delivery, Just-in-Time logistics, lookahead planning, and direct-to-install lifting. Although the proposed configuration has not been empirically validated, it provides a practical framework for reducing non-value-adding activities and improving workflow coordination in precast façade installation.

Keywords : Value Stream Mapping; Lean Construction; Construction Waste; Precast Façade; High-Rise Building; Workflow Coordination

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1. INTRODUCTION

The need for construction techniques that may achieve dependable project performance while ensuring quality, safety, and effective resource usage has increased due to the growing construction of high-rise residential buildings in densely populated urban regions. Because building components may be produced under controlled conditions and then transported to construction sites for installation, precast concrete technology has emerged as a significant construction method in this context. Precast technologies can offer more consistency in component quality, dimensional correctness, and construction planning as compared to traditional cast-in-situ production. Nevertheless, effective on-site performance is not always ensured by the advantages of prefabrication. Coordination of production, transportation, temporary storage, lifting equipment, work-front readiness, and installation activities all contribute to a precast system's efficacy. Recent research on strategic prefabrication also points to the importance of integrating production arrangements with downstream construction needs rather than evaluating factory efficiency alone (Lauble et al., 2025). According to recent studies, the use of lean concepts to precast construction has drawn more interest since lean tools can improve material flow, cut waste, and boost precast processes' overall effectiveness (Parameswaran et al., 2025).

Non-value-adding (NVA) activities continue to be a major problem in construction projects, notwithstanding the benefits of precast technology. Excessive inventory, waiting, overproduction, needless movement, and process disruptions are examples of activities that use resources but do not directly contribute to the essential project output. According to (Malika et al., 2024), the precast industry's main NVA activities include needless inventory, waiting times, overproduction, and needless movement. They also highlighted the need of using lean tools to minimize these activities.

Through the creation of a current-state map and a suggested future-state map, (Nurlaelah, 2022) illustrated the use of Value Stream Mapping (VSM) in the Indonesian construction context to identify building waste in a low-cost housing project. An important foundation for using VSM in Indonesian building processes was provided by this study. However, there are significant differences between the features of high-rise precast façade installation and low-rise housing construction, especially with regard to lifting operations, vertical material movement, temporary storage, work-front availability, and synchronization between logistics and installation activities.

Value Stream Mapping (VSM) offers a methodical way to visualize information and material flows and separate operations that create value from those that don't. Research on its use in precast construction has grown. VSM and Just-in-Time (JIT) are two of the most common Lean approaches used in precast construction, according to a critical analysis of 35 papers on the subject (Parameswaran et al., 2025). The evaluation also highlighted how Lean technologies may boost client value, save waste, and make precast construction processes more sustainable. According to these results, VSM is especially important for precast construction since the system's total success is dependent on the synchronization and continuity of related operations rather than the effectiveness of individual tasks.

Additionally, recent studies have started to expand VSM to include façade-related activities. For instance, (Georges et al., 2026) proved the value of current-state and future-state VSM in detecting workflow inefficiencies and creating Lean-based improvement strategies by applying it to the façade engineering delivery process. In façade-related activities, their study emphasizes the significance of coordination, information flow,

rework, delays, and bottlenecks. While the actual installation of precast façade panels involves additional operational constraints such as material delivery, temporary inventory, crane availability, lifting sequence, work-front readiness, and installation coordination, façade engineering delivery is primarily focused on the engineering and information-delivery process. As a result, more empirical research is needed to determine the workflow features and waste sources during the physical installation step.

Therefore, the study need encompasses not only the identification of construction waste but also the connections between various waste categories in the precast façade installation process on-site. Previous studies have examined VSM in general construction, NVA activities in the precast industry, Lean applications in precast production, and VSM-based examination of façade engineering delivery. The relationship between material delivery, temporary inventory, lifting readiness, work-front availability, and installation operations in high-rise precast façade projects, however, has received little study.

This relationship is crucial because, while inadequate synchronization between material availability, lifting equipment, and work-front preparedness may result in waiting and disrupt installation continuity, premature delivery may raise temporary inventory and additional handling. As a result, analyzing waste categories separately might not adequately address the root reasons of inefficient process. By integrating material flow, information flow, installation activities, and construction waste into a unified workflow, a macro-level VSM perspective can offer a more comprehensive picture.

The current study expands its analytical reach while building upon the authors' prior research trajectory. In order to demonstrate the value of VSM for building-process analysis in Indonesia, (Nurlaelah, 2022) concentrated on the application of VSM for identifying construction waste in affordable housing. More recently, the precast façade construction process of a high-rise residential building in Jakarta was theoretically examined by (Nurlaelah, Alhanif, Basit, Fitriani, 2026) using VSM as a Lean Construction tool. Workflow fragmentation and synchronization issues between equipment availability, installation readiness, and material delivery were found to be significant drivers of inefficiency in that study.

By shifting from a primarily process-based VSM analysis to an empirically integrated diagnostic assessment that combines planned versus actual installation achievement, perception-based assessment of the seven construction waste categories, site observations, and macro-level VSM, the current study expands on earlier research. The connections between waiting, inventory, overproduction, and overprocessing, as well as how these wastes manifest in the installation workflow, are given special consideration. Therefore, the present study's contribution goes beyond just applying VSM to another apartment building; rather, it incorporates installation-performance evidence and systematic waste evaluation into the diagnosis of precast façade installation workflow.

The study focuses on the installation of precast façades on Floors 8–12 of a high-rise housing complex in Ciracas, East Jakarta, Indonesia. Spatial constraints, vertical transit, lifting operations, material storage, and project participant coordination can all affect installation continuity in this dense urban construction environment. Crane scheduling research in prefabricated construction further highlights the complexity of coordinating shared lifting resources under changing operational demands (Yin et al., 2024). The study intends to: (1) compare planned and actual installation quantities to assess the success of precast façade installation; (2) identify the predominant construction waste categories related to the installation process;

and (3) use macro-level Value Stream Mapping (VSM) to investigate how the identified wastes are reflected in the material and installation workflow and (4) create a suggested Future-State VSM based on the workflow issues found. Through pull-based material delivery, just-in-time logistics, lookahead planning, installation-readiness confirmation, and direct-to-install lifting, the proposed Future-State VSM aims to improve synchronization. The Future-State VSM's efficacy is not asserted as an empirically validated enhancement because it is suggested rather than used in the project. Rather, it offers a defined workflow configuration that can be further examined and verified in subsequent studies.

Literature Review

VSM and construction waste identification

Value Stream Mapping has been applied in construction projects to examine material flows, identify non-value-adding activities, and understand the sources of operational inefficiencies. Vilventhan et al. (2019) demonstrated the use of VSM to identify and assess material waste in a high-rise building project. Similarly, Ramani and KSD (2021) applied current-state and future-state mapping to identify opportunities for improving construction activities. These studies indicate that VSM can provide a systematic basis for examining construction workflows and identifying potential areas for improvement. Chen et al. (2023) extended VSM to off-site production of reinforced concrete slabs, while Cunha et al. (2025) used VSM to reveal information-flow and coordination opportunities in modular-construction design.

Waste and material coordination in prefabricated construction

Waste in construction is not limited to material losses but also includes delays, unnecessary handling, excessive inventory, and inefficient resource utilization (Moradi & Sormunen, 2023). These issues are particularly relevant to prefabricated construction, where material delivery needs to be coordinated with the installation schedule. The procurement model of Chen et al. (2023) explicitly considers supply capacity, construction schedules, and costs, while Zhang et al. (2024) examined just-in-time coordination of prefabricated component logistics. Zeng et al. (2022) highlighted the importance of just-in-time purchasing and supply chain coordination in reducing the handling costs associated with early or delayed delivery of prefabricated components.

Research context in Indonesia

Empirical studies in Indonesia have also examined construction waste through Lean Construction approaches. Anggraini et al. (2022) combined VSM with waste assessment techniques to identify major sources of inefficiency in a building project. Firdaus et al. (2025) further investigated construction waste through questionnaires distributed to construction professionals. Nevertheless, these studies provide a broader construction perspective, leaving room for further investigation into the specific workflow constraints associated with precast façade installation in high-rise buildings. Recent waste-identification research also emphasizes that survey-based assessments can help prioritize site inefficiencies, but must be interpreted in relation to the construction processes being studied (Mitera-Kiełbasa & Zima, 2025).

2. METHODS

2.1 Research Design

In order to examine construction waste and workflow inefficiencies in the precast façade installation of a high-rise apartment building in Jakarta, Indonesia, this study used a quantitative descriptive case study. In order to analyze the total flow of materials, information, and installation operations and to pinpoint the main sources of non-value-adding activities, the study used a macro-level Value Stream Mapping (VSM) approach.

There were four primary analytical components to the study. First, the number of precast façade panels actually built on Floors 8–12 was compared to the projected installation target in order to assess the actual installation achievement. Second, construction professionals' opinions about the prevalence of seven construction waste types derived from the Lean Construction framework were gathered using a structured questionnaire. Third, using macro-level VSM, the detected waste categories were connected to the

installation workflow that was observed. Ultimately, based on the predominant wastes and workflow bottlenecks found in the Current-State VSM, a Future-State VSM was created as a suggested improvement configuration.

The primary goals of the study's design were diagnostic and descriptive. As a result, the suggested Future-State VSM was not considered an implemented intervention, and there was no statistical validation of its impacts on waste reduction or productivity.

2.2 Case Study and Respondents

The installation of precast façade panels in a high-rise housing complex in Jakarta, Indonesia, was the subject of the case study. Because planned and actual installation quantities were available, the investigation concentrated on Floors 8–12.

The questionnaire survey was completed by thirty-three construction professionals. The selection of respondents was based on their understanding of the precast façade installation procedure and their participation in construction activities. Project managers, site engineers, supervisors, quality control engineers, foremen, and other construction workers were among the various project jobs represented by the respondents (Table 1).

Foremen made up the largest responder group (30.3%), followed by supervisors (24.2%) and site engineers (18.2%), as shown in Table 1. 42.4% of respondents had less than five years of work experience, 30.3% had five to ten years, and 27.3% had more than ten years. In terms of project involvement, 45.4% had been working on the project for six to twelve months.

Table 1. Respondent Profile

Characteristics	Category	Frequency	Percentage (%)
Position	Project Manager	2	6.1
	Site Engineer	6	18.2
	Supervisor	8	24.2
	QC Engineer	4	12.1
	Foreman	10	30.3
	Others	3	9.1
Working Experience	<5 years	14	42.4
	5–10 years	10	30.3
	>10 years	9	27.3
Project Involvement	<6 months	8	24.3
	6–12 months	15	45.4
	>12 months	10	30.3
Total		**33**	**100.0**

Personnel directly involved in planning, supervision, quality control, and field implementation were represented among the responders. Because construction waste in precast façade installation may occur across multiple interconnected activities rather than only at the installation site, this was deemed pertinent.

2.3 Research Instrument

A systematic questionnaire with 14 statements representing seven categories of construction waste—two statements for each category—was used to collect data on building trash (Table 2). Waiting, transportation, motion, inventory, defects, overproduction, and overprocessing were the seven categories.

A five-point Likert scale, with 1 denoting Very Low and 5 denoting Very High, was utilized in the questionnaire. The purpose of the questionnaire was to gather respondents' opinions about the prevalence of construction waste during the installation of precast façades.

Table 2. Questionnaire Categories and Measurement Items

No	Waste Category	Number of Items	Statement
1	Waiting	2	Workers experience delays while waiting for crane availability before installing façade panels.
2	Transportation	2	Façade panels are transported multiple times before reaching the installation location.
3	Motion	2	Workers frequently travel long distances to obtain tools or materials required for installation.
4	Inventory	2	Precast façade panels remain stored on-site longer than scheduled before

No	Waste Category	Number of Items	Statement
			installation.
5	Defects	2	Installed façade panels require repair or reinstallation because of quality deficiencies.
6	Overproduction	2	Façade components are delivered earlier than the installation schedule requires.
7	Overprocessing	2	Certain installation procedures involve unnecessary activities that do not add value.
	Total	**14**	

2.4 Validity and Reliability Consideration

Thirty-three respondents completed the 14-item questionnaire. Nevertheless, at the time of the current research, the original respondent-level dataset was unavailable. As a result, the remaining aggregated data could not be used to replicate statistical validity and reliability tests, such as item-level Pearson correlation and Cronbach's alpha.

This study does not publish reconstructed validity coefficients or reliability estimates in order to retain methodological transparency. As a result, the questionnaire findings are not regarded as proof of a statistically verified psychometric tool but rather as descriptive perceptual data.

The macro-level VSM analysis, installation achievement statistics, and questionnaire results were all interpreted. The interpretation of the predominant waste categories and their connection to the observed construction workflow was strengthened by this triangulation. A study of waste time during structural works in Indonesia likewise illustrates the use of VSM to interpret non-value-adding activities within a specific work sequence (Dewi & Sapitri, 2024).

2.5 Data Collection

Questionnaire answers, project installation data, and process observations/documentation were the three complementing information sources that were utilized. The seven categories of building waste were evaluated for perceived occurrence using the questionnaire. The anticipated installation goals and actual installation quantities for Floors 8–12 were presented in the project documentation. The order of precast façade installation activities, material transportation, temporary storage, lifting operations, installation activities, and other pertinent workflow conditions were all understood through field observations.

The study was able to differentiate between perceived waste occurrence and observed workflow circumstances thanks to the integration of these data sources. Specifically, the answers of the questionnaire were analyzed in connection to the installation achievement and Current-State VSM rather than being interpreted independently.

2.6 Data Analysis Technique

Three principal analytical procedures were applied.

2.6.1 Installation Achievement Analysis

Installation achievement was calculated by comparing the number of installed panels with the corresponding SOP target:

$$IAi = Ai/Ti \times 100\ \%$$

where:

- IA = installation achievement on floor ii;
- Ai = actual number of installed panels on floor ii;
- Ti= SOP target on floor ii.

Overall installation achievement was calculated using the total actual installation quantity divided by the total planned quantity:

$$IAoverall= \sum Ai/\sum Ti \times 100\%$$

The arithmetic mean of the floor-level percentages was presented separately to explain the variation across specific floors, while the

overall achievement served as the primary indicator of installation performance.

2.6.2 Construction Waste Analysis

Questionnaire responses were coded from 1 to 5 according to the Likert scale. Mean scores were calculated for each waste category:

$$\bar{X} = \sum Xj / n$$

where:

- $\bar{X}$ = mean score;
- Xj= respondent score;
- n = number of respondents.

The mean scores were subsequently ranked from the highest to the lowest value.

The interpretation criteria were:

Mean Interval	Interpretation
1.00–1.80	Very Low
1.81–2.60	Low
2.61–3.40	Moderate
3.41–4.20	High
4.21–5.00	Very High

2.6.3 Macro-Level Value Stream Mapping

To depict the main information and material flows related to precast façade installation, a Current-State VSM was created. Activities like material preparation and delivery, temporary storage, lifting, installation, and subsequent process activities found during field observation were all included in the macro-level analysis of the process. This integrated process perspective is consistent with Naser (2025), who proposed combining VSM, advanced work packaging, and the Last Planner System to visualize constraints and improve construction coordination.

Every activity was divided into three groups:

- **Value-Adding (VA):** activities that directly contribute to producing the required completed façade installation.
- **Necessary but Non-Value-Adding (NNVA):** activities that do not directly transform the required output but are currently necessary because of technical, safety, quality, coordination, or project requirements.
- **Non-Value-Adding (NVA):** activities that consume time or resources without contributing to the required output and that can potentially be eliminated or reduced.

Activities related to waiting, excessive temporary storage, needless material transportation, early delivery, flaws, and needless processing received special attention. The workflow circumstances shown in the Current-State VSM were then compared with the waste categories found in the questionnaire. The study was able to determine connections between workflow inefficiencies and prevalent waste categories thanks to this procedure.

Lastly, based on the bottlenecks found, a Future-State VSM was suggested. Pull-based material delivery, Just-in-Time (JIT) logistics, lookahead planning, direct-to-install lifting, and enhanced coordination between material supply and installation schedule were all part of the suggested setup. The Future-State VSM is a suggested improvement scenario rather than a proven intervention because these tactics were not used in the case study.

3. RESULTS AND DISCUSSION

3.1 Precast Façade Installation Achievement

The comparison between planned and actual precast façade installation on Floors 8–12 is presented in Table 4.

Table 3. Planned and Actual Precast Façade Installation on Floors 8–12

Floor	SOP Target (Units)	Installed Panels	Gap (Not Installed)	Achievement Percentage
8	100	64	36	64.00%
9	100	57	43	57.00%
10	97	74	23	76.29%
11	108	36	72	33.33%
12	118	27	91	22.88%
Total	**523**	**258**	**265**	**49.33%***
Mean floor-level achievement	—	—	—	**50.70%**

The findings show that the actual and planned installation volumes differ significantly. Only 258 of the 523 panels

intended for Floors 8–12 were installed, leaving a 265-panel gap. The entire installation achievement was 49.33% based on the total planned and actual quantities.

Floor 10 achieved the highest floor-level percentage of 76.29%, followed by Floor 8 at 64.00% and Floor 9 at 57.00%. On Floors 11 and 12, on the other hand, installation achievement significantly decreased to just 33.33% and 22.88%, respectively.

The five floor-level achievement percentages had an arithmetic mean of 50.70%. This number should be contrasted from the overall achievement of 49.33%, though, as the latter is determined by adding the total planned and actual quantities, while the former assigns equal weight to each floor.

The installation workflow may not have been continuously in line with the intended installation aim, as seen by the decreased achievement on the upper floors. The growing installation gap—especially on Floors 11 and 12—offers a crucial clue that productivity limitations might have accrued over the course of installation.

Nevertheless, the installation data by itself cannot pinpoint the precise reasons behind the performance disparity. Consequently, the results of the waste analysis and VSM are utilized to investigate the possible workflow-related issues connected to this scenario.

3.2 Construction Waste Analysis

The questionnaire results identified substantial differences in the perceived occurrence of the seven construction waste categories. Table 5 presents the mean scores and their corresponding classifications.

Table 4. Mean Scores and Ranking of Construction Waste Categories

Rank	Waste Category	Mean	Category
1	Waiting	4.42	Very High
2	Inventory	4.42	Very High
3	Overproduction	4.36	Very High
4	Overprocessing	4.36	Very High
5	Defect	3.30	Moderate
6	Transportation	2.85	Moderate
7	Motion	2.48	Low

With a mean score of 4.42, which falls into the "Very High" category, waiting and inventory were found to be the most prevalent waste categories. Overproduction and Overprocessing, each with a mean score of 4.36, came next.

The comparatively high waiting and inventory scores show that respondents thought there were a lot of disruptions and material buildup during the façade installation process. Installation activities in a precast façade system are heavily reliant on the timing and availability of various resources, including lifting equipment, installation teams, façade panels, and work-front preparedness. When these components are not synchronized, personnel may be prepared while materials or lifting resources are unavailable, or materials may be accessible before they can be placed.

The features of precast façade construction are especially pertinent to the high inventory score. Due to their size and need for careful handling, façade panels may need to be temporarily stored at the project site if they are delivered too soon. In addition to taking up space, this kind of storage could necessitate more handling and transportation. For prefabricated components, optimized delivery management has been proposed to reduce overstock costs while accommodating schedule uncertainty (Zhang & Zhang, 2024).

On the other hand, the high overproduction score suggests that respondents thought parts were provided ahead of schedule for installation. Therefore, overproduction in this study is more closely associated with material-flow synchronization than with production amount alone. Research on data-driven logistics collaboration similarly stresses the need to connect production, storage, transport, and assembly decisions in prefabricated supply chains (Yang et al., 2024).

Additionally, overprocessing scored really well. This implies that there are operations in the installation procedure that are thought to be superfluous or excessive. Repeated handling, extra coordination, or procedural processes that don't directly contribute to finished façade installation are examples of such activities. Rather than being direct causal measurements, these interpretations should be viewed as workflow-related impressions.

A moderate score of 3.30 was given to defects. This shows that while quality-related rework existed, waiting, inventory, overproduction, and overprocessing were seen as more important. The mean scores for mobility and transportation were 2.48 and 2.85, respectively. Motion was categorized as low, and transportation as moderate. These findings imply that, in contrast to delays and material accumulation, needless worker mobility and excessive transportation were not thought to be the main causes of waste.

Overall, the ranking shows that the synchronization of material availability, installation readiness, and project workflow—rather than just the actual transportation of labor or materials—was the case project's main problem.

3.3 Current-State Workflow and Value Stream Mapping

While the macro-level VSM offers a process viewpoint for comprehending where these wastes may originate, the waste ranking indicates which waste kinds were thought to be most prevalent.

The primary order of precast façade installation activities is represented by the Current-State VSM, which starts with material availability and delivery and moves on to temporary storage, lifting, positioning, installation, and other process activities. The pertinent project staff must coordinate information about installation needs, work-front preparedness, material availability, and schedule along this flow.

The findings show that waiting and inventory might interact rather than being separate wastes. When the installation work front or lifting capability is not yet available, for instance, early delivery of façade panels may result in an increase in temporary inventory. On the other hand, workers may have to wait because the necessary panels are not accessible when installation operations are scheduled if material delivery is not in line with the installation timetable.

This interaction can create a recurring pattern:
premature delivery → temporary inventory → additional handling/storage → workflow disruption
or:
installation readiness → material unavailability → waiting → reduced installation output

Because material mobility depends on lifting capability, floor access, work-front preparation, and coordination between several project activities, these interactions are especially crucial in the installation of high-rise precast façades. In a related prefabrication setting, Wang et al. (2024) developed a just-in-time transport-planning approach, emphasizing delivery timing as an explicit logistics decision.

Therefore, by demonstrating that the primary wastes are interconnected within the material and information flow rather than occurring individually, the VSM enhances the results of the questionnaire. Wang et al. (2023) also demonstrate that disruptions can propagate through interconnected prefabricated-building supply-chain activities, reinforcing the value of examining material flow as a system.

3.4 Relationship Between Waste and Installation Performance

Complementary information regarding the status of the project process is provided by the waste rating and installation accomplishment outcomes.

The overall installation accomplishment of 49.33% indicates that slightly less than half of the planned panels have been put throughout Floors 8–12. Concurrently, the highest perceived waste scores (4.42) were given to inventory and waiting, followed by overproduction and overprocessing (4.36).

These findings all indicate that process synchronization is a serious issue that has to be resolved. This diagnostic reading is consistent with Lagos et al. (2024), who studied the value of production-planning metrics for anticipating construction schedule performance, although their predictive model is distinct from the descriptive analysis used here. High waiting implies interruptions in the continuity of installation efforts, whereas high inventory suggests that material availability was not always in accordance with installation readiness. High overproduction further supports the possibility of early material supply relative to installation requirements.

However, the available data does not allow for statistical analysis of a causal relationship between waste ratings and installation achievement. Therefore, it is inappropriate to interpret the results as demonstrating that a particular waste category was directly responsible for the 49.33% installation performance.

Instead, the findings supports a diagnostic interpretation: the low installation achievement occurred in a workflow environment characterized by considerable perceived delay, inventory, overproduction, and overprocessing. The VSM study provides a process-based explanation of the potential interconnections between these wastes. This distinction is important since the study uses aggregated questionnaire results and project-level installation data instead of inferential statistical analysis at the respondent level.

3.5 Proposed Future-State Value Stream Mapping

A Future-State VSM was created as a suggested improvement configuration based on the Current-State VSM and the predominant waste categories. Improving the synchronization of material supply, lifting resources, work-front readiness, and installation operations is the main goal of the proposed Future-State VSM. There are four primary approaches suggested.

3.5.1 Pull-Based Material Delivery

Instead of being predominantly determined by upstream production or supply schedules, material delivery should be connected to actual installation requirements. By preventing early delivery of façade panels, a pull-based strategy can help cut down on needless temporary inventory. Liu et al. (2024) investigated just-in-time scheduling for precast bridge girders, providing further evidence of the importance of matching upstream production to downstream delivery windows.

4.5.2 Just-in-Time Logistics

JIT logistics can be used to schedule the delivery of façade panels in accordance with the availability of lifting and installation equipment. Reducing needless buildup and repetitive handling is the goal rather than getting rid of all on-site inventory. Transport optimization by Wang et al. (2024) and uncertainty-aware component delivery management by Zhang and Zhang (2024) offer related logistics perspectives, although neither was implemented in this case project.

3.5.3 Lookahead Planning

Prior to the planned installation period, lookahead planning should be performed to determine forthcoming installation requirements, work-front preparation, crane availability, material requirements, and any restrictions. Planning and field execution may be better coordinated as a result. Agrawal et al. (2024) identified automation opportunities across Last Planner System stages, particularly lookahead planning, while Power et al. (2024) discussed integrating Last Planner and takt-based production planning.

3.5.4 Direct-to-Install Lifting

Façade panels can be supplied and raised as close to their intended installation sequence as feasible when site conditions allow, minimizing needless temporary storage and repetitive material handling. The scheduling model presented by Yin et al. (2024) emphasizes the significance of crane dispatch decisions, and Ding et al. (2025) examined dynamic synchronization under disruptions in an off-site prefabrication setting.These proposed strategies are summarized conceptually as Figure 1:

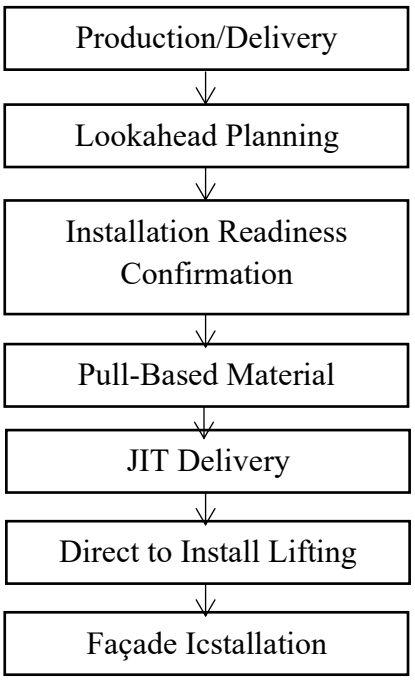


Figure 1. Proposed Strategy

The goal of the suggested setup is to lessen the interplay between overproduction, inventory, and waiting. Additionally, it offers a foundation for enhancing the synchronization of information and material flows.

Crucially, the case project did not employ or validate the Future-State VSM experimentally. As a result, rather than being proven productivity gains, the suggested tactics should be viewed as suggestions for improvement. The suggested arrangement should be put into practice in future studies, and its impacts should be assessed using quantifiable metrics such installation cycle time, waiting time, material handling frequency, inventory duration, and installation productivity. Future evaluations could also investigate digitally enabled VSM approaches, as reviewed by Mora et al. (2025), while preserving the distinction between simulated benefits and measured field outcomes.

3.6. Discussion

The results show that workflow coordination and material-flow synchronization are the primary obstacles in the precast façade construction process under investigation. The overall installation accomplishment of 49.33% shows that the actual and planned installation amounts differ significantly. In the meantime, waiting and inventory are the most prevalent perceived waste categories, according to the waste assessment.

The findings align with the core tenet of Lean Construction, which holds that construction success is dependent on both the continuity and coordination of the entire production flow as well as the effectiveness of individual tasks. Installation of a precast façade system depends on a series of interrelated tasks. Material delivery, lifting, work-front availability, and following installation activities might all be impacted by an interruption in one activity.

It is especially crucial when there is a lot of waiting and inventory. At first glance, these two wastes could seem incompatible: workers might have to wait for supplies or equipment, while materials might be building up elsewhere on the site. However, from a value-stream standpoint, both situations may arise when the installation and material flows are not in sync. The supply-chain coordination findings of Yang et al. (2024) and the broader risk-propagation analysis by Wang et al. (2023) provide parallel explanations for how local disruptions can affect downstream activities.

In a similar vein, the high overproduction score emphasizes how crucial it is to manage the schedule of material supply. Delivering façade parts before the front of the installation work is ready could result in more inventory without more finished installations.

Therefore, rather than only speeding up individual installation tasks, the suggested Future-State VSM places more emphasis on flow synchronization. To better align material supply with real installation need, pull-based delivery, JIT logistics, lookahead planning, and direct-to-install lifting are suggested. Emblemsvåg (2024) further argued for combining process-oriented lean planning with established project controls, an approach relevant to monitoring whether proposed workflow changes translate into reliable execution.

However, there is a significant methodological flaw in the study. Item-level validity and reliability testing could not be replicated since the original respondent-level questionnaire dataset was no longer accessible. As a result, installation achievement and VSM observations are used to triangulate the descriptive interpretation of the questionnaire data. Furthermore, the Future-State VSM has not been empirically implemented or tested; it is merely a suggested configuration.

Notwithstanding these drawbacks, the study offers a useful framework for identifying construction waste during the installation of precast façades. Installation achievement analysis, waste perception rating, and macro-level VSM work together to identify interrelated workflow issues and offer an organized framework for creating solutions for change.

4. CONCLUSION

4.1 Conclusion

This study shows that there was a significant discrepancy between the intended and actual installation output in the precast façade installation procedure examined in the

high-rise residential project. Only 258 of the 523 intended façade panels were erected across Floors 8–12, yielding an overall installation achievement of 49.33%. This result shows that the installation flow was not consistently synced with the intended production and delivery requirements, rather than being understood as a single productivity indicator.

Waiting and inventory were found to be the most common perceived waste categories, followed by overproduction and overprocessing, according to the waste assessment. When these results are combined with the macro-level VSM, it becomes clear that coordinating material availability, work-front readiness, lifting operations, and installation timing was the main obstacle. Specifically, when installation conditions are not appropriate, early material delivery may result in temporary inventory, and inadequate synchronization may concurrently cause waiting at the installation front.

Therefore, the study emphasizes the usefulness of macro-level VSM as a diagnostic technique for precast façade construction, especially when waste is produced by interactions between related activities rather than by a single operation. The importance of VSM and JIT for lowering non-value-adding activities in precast construction and enhancing the alignment between material flow and production requirements is further highlighted by recent study (Parameswaran et al., 2025).

The study suggests a Future-State VSM focused on pull-based material delivery, Just-in-Time logistics, lookahead planning, and direct-to-install lifting based on the conditions found. These tactics offer a workable foundation for enhancing workflow coordination and cutting down on needless waiting and material accumulation. However, its efficacy should be viewed as a suggested improvement rather than an experimentally proven performance gain because the suggested Future-State VSM was not put into practice throughout the investigation.

This study's overall contribution is the integration of value-stream analysis, perceived construction waste, and installation success into a unified diagnostic framework for precast façade installation. The results highlight how crucial it is to manage construction flow as a cohesive system as opposed to optimizing individual installation tasks separately.

4.2 Recommendations

Based on the findings, several recommendations are proposed for both construction practice and future research.

4.2.1 Recommendations for Construction Practice

First, a pull system based on readiness and demand should replace a schedule-driven approach to material delivery. Based on verified installation specifications, work-front preparedness, and lifting availability, façade panels should be made available for delivery. According to current research, JIT and VSM are two of the most commonly used Lean strategies in precast construction, making this approach very pertinent (Parameswaran et al., 2025).

Second, the project should improve short-term coordination and lookahead planning between the lifting, installation, logistics, and production teams. The availability of panels, crane capacity, access circumstances, installation teams, and work-front preparation should all be collaboratively verified prior to each installation cycle. This can lessen the likelihood that workers will have to wait while supplies or equipment are unavailable.

Third, if site conditions permit, direct-to-install logistics should reduce the need for temporary storage. Reducing intermediate storage can enhance material flow continuity and reduce additional handling. This suggestion is in line with recent research that found waiting and needless inventory to be significant sources of non-value-adding activity in the precast sector (Malika et al., 2024).

Fourth, project teams should establish a simple visual monitoring system that connects planned installation quantities, actual installation quantities, material delivery status, and unresolved constraints. Such monitoring can provide early warning when installation performance begins to deviate from the planned target.

4.2.2 Recommendations for Future Research

Instead of depending only on the conceptual advantages of the suggested Future-

State VSM, future study should empirically evaluate it. Waiting time, inventory duration, material handling frequency, installation cycle time, installation productivity, and schedule dependability might all be measured in a before-and-after implementation design.

It is also advised to use digital simulation and VSM. The possibility of combining VSM with discrete-event simulation to assess Current-State and Future-State scenarios prior to actual deployment has been shown by recent research. For high-rise precast façade projects, when crane capacity, delivery schedule, floor access, and installation order are highly interrelated, this strategy may be especially helpful.

Finally, future studies should retain the individual respondent-level questionnaire dataset so that item-level validity and reliability can be formally assessed and reproduced. Combining validated perception measures with objective process data would provide stronger evidence for examining the relationship between construction waste and installation performance. This is also consistent with the emphasis on transparent, measurable production-flow information in recent work on digitally supported VSM and planning systems (Mora et al., 2025; Agrawal et al., 2024).

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