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IDENTIFICATION OF PRODUCTIVITY VALUES USING THE METHOD PRODUCTIVITY DELAY MODEL ON WALLER BEAM WORK

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Abstract

Productivity can be interpreted as a comparison between physical output and real output with the actual input. This research aims to identify labor productivity on waller beam installation work in construction projects using the Method Productivity Delay Model (MPDM). The research method is carried out by conducting direct observations in the field and collecting productivity data using MPDM which is applied through delay analysis in the production cycle, techniques for evaluating work team balance and ensuring optimal labor allocation. The results showed that several factors, such as the environment contributing to the waller beam installation contributed 0.04, equipment factor contributed 0.21, labor factor contributed 0.36, material factor contributed 0.15, and management by 0.02 contributed to the delay and lower productivity. Ideal productivity was obtained at 1.737 units/s, overall productivity at 1.486 units/s, and % Achieved Productivity based on Ideal Productivity at 85.54%. In addition, the findings also emphasize the importance of proactive planning and real-time monitoring to reduce productivity losses and improve construction project performance.

Keywords: Labor Productivity, Method Productivity Delay Model, Ideal Productivity

Introduction

Construction projects are activities in which workforce productivity significantly impacts the final outcome of the work (Sangadji, 2023). Productivity can be defined as the relationship between the physical and tangible results and the actual inputs (Kartika et al., 2021; Norjana & Zulfiati, 2020). High productivity results benefit the project by enabling timely completion, efficient spending, and high product quality (Massie et al., 2022; Putujaya, 2020). The most common problems in construction projects are delays and cost overruns, which can result in lost productivity (Irawan & Thesisa, 2024; D. A. Putri et al., 2021; Tumilantouw, 2024).

Effective workforce management and optimization can have a significant impact on project outcomes, with strategies focused on improving skills, motivation and teamwork being key to maintaining high levels of productivity in the field (Van Tam, 2024). Construction project human resources are potential skills and capacities that can be best utilized to support the implementation of construction activities (Rompas, 2022). Human resources play an important role in the construction industry and the limited labor force can be an obstacle in the implementation of work at the same time (Lendra et al., 2023).

Productivity in the implementation of construction work which is an important parameter is the timeliness of work implementation (Prayoga Arfandi & Abduh, 2021). The amount of productivity value generated is strongly influenced by labor productivity to complete a task from start to finish can calculate the productivity of a job. Work productivity is influenced by three things: equipment, materials, and labor (Dharmawan, 2020). Worker productivity measurement is a crucial factor in determining the success of a construction project, but its consideration is often overlooked due to the complexity of productivity issues influenced by internal and external factors (Desfita & Hamid, 2021).

The overall success of a construction project relies on the successful completion of each individual task, with workforce productivity being a key factor influencing job performance (A. Gunawan & Setyawan, 2022; Putri Angelica & Happy Puspasari, 2023). The supporting work for Project X located in South Jakarta occurred in the supporting work of the Diaphragm Wall (D-Wall) structure. In deep diaphragm wall projects, the waller beam/strutting plays an important role in maintaining soil stability, reducing deformation and preventing collapse (Michelle Susanto & Jonathan Susilo, 2022).

Improper installation of wall joists or bracing on D-Walls can result in structural failure, cause delays in construction due to repairs, and may result in settlement or cracking of buildings in urban areas (Malik et al., 2019; Widjaja & Makarim, 2020). A study on labor productivity in light brick wall installation for a residential construction project in Surabaya recorded an average of 1.247 m^2 per person-hour, with observed productivity ranging from 1.125 m^2 to 1.344 m^2 per person-hour (Dwipurwanto, 2023). While in the study, the productivity of the 1st floor red brick wall installation work was 9.03 m^2/day and the 2nd floor 7.03 m^2/day (Putu Raka Wibawa, 2020).

Research on labor productivity in the installation of prefabricated walls and lightweight brick on the cost and time on the facade of the Suncity Sidoarjo Apartment Project, prefabricated walls take 113.86 days ~ 3 months more 26 days, while the implementation of lightweight brick wall work takes 154 days ~ 5 months more 4 days (Hanifah Eka Putri et al., 2021). While the productivity value of laborers is 2.2498 m^2/person/hour on the 1st floor and 2.2008 m^2/person/hour on the 2nd floor (Noor Syaima Mooniana & Eliatun, 2024). This allows for further action to be taken to ensure work efficiency through the application of the Method Productivity Delay Model (MPDM).

Method Productivity Delay Model (MPDM) is a technique used to assess, forecast, and improve productivity in a construction method by analyzing delays that occur in several operation cycles (Januardi et al., 2024). Delays in construction can reduce productivity levels and generally occur frequently during implementation (Cahyono et al., 2022). Various factors can cause delays in construction projects. Environmental factors, such as shifts in soil conditions, alterations in wall structures, and adverse weather like rain, often serve as obstacles that disrupt the smooth progress of work. In addition, delays can also occur due to equipment that is still in transit or in the process of being moved, experiencing damage, or not operating at maximum capacity. Labor factors also contribute to delays, for example when workers have to wait their turn, experience fatigue, or are less productive due to a lack of knowledge and skills.

The Method Productivity Delay Model (MPDM) is applied in this study due to its proven effectiveness in measuring and analyzing construction productivity (Halpin & Riggs, 1992; Irfanto et al., 2024). In order for construction projects to run smoothly, there are five main factors that cause delays, namely the environment, equipment, labor, materials, and project management, which can guide the project from the beginning of planning, through implementation, to the end of the project (Fauzi et al., 2022; I. Gunawan et al., 2025; Wenas et al., 2023).

Based on a review of research data collection in the field, which was achieved in the 1st cycle of 2760.18 seconds with the 2nd cycle achieved 626.50 seconds. In reality, there is a problem with this research regarding a decrease in labor productivity, which causes work to not be done optimally. Through a comprehensive analysis of delay factors such as environment, equipment, labor, materials, and management, this study provides deeper insights and practical solutions to improve overall project efficiency (Jefferson & Andi, 2023; Wijaya, 2022). The study was conducted to identify the factors contributing to decreased productivity and to formulate solutions to improve project performance (Adebowale & Agumba, 2023; Bamayi et al., 2022; Dharsono & Hindun, 2024).

Retaining wall works are a vital early part of the substructure activities, but often show relatively low progress in the early stages of construction. Retaining wall reinforcement systems generally use elements such as ground anchors and strutting, but are not equipped with the use of waller beams as horizontal load distribution elements between anchor points (Maharani et al., 2022; Sri Mulyati, 2024). The absence of such waller beams can potentially lead to uneven force distribution, which in turn can affect the long-term stability of the overall retaining structure. In fact, in deep excavation works, waller beams play a crucial role in resisting the lateral force of the soil so that the walls do not deform excessively. Its use can increase the stiffness of the reinforcement system and maintain the geometric integrity of the retaining wall during the construction process.

Applying the Method Productivity Delay Model, this study identifies the level of productivity in waller beam installation for factors that cause delays and decreased efficiency. Through the use of MPDM, productivity can be accurately measured and project management can anticipate potential problems before they occur (Tanne et al., 2024). Therefore, it is hoped that by conducting research on this object, the results can be used to improve productivity on similar projects with high technical challenges (A. N. Putri, 2021). While there have been many studies on productivity in construction, the specific application of the Productivity Delay Model to waller beam installation work is limited and has not been documented in the current literature. This research adds value by bridging the gap through presenting a focused insight into a vital yet often overlooked element of excavation work. In addition, this study offers a structured approach to identify and mitigate inefficiencies in complex excavation support systems, potentially increasing productivity on technically challenging projects.

Research Methods

Observations and data collection were conducted on Construction Project X located in Senopati, South Jakarta. The project started in 2023 and is scheduled to be completed by the end of 2026. Observation and data collection were carried out on one team at each stage of the work. Data collection began on August 1, 2024, coinciding with the waller beam installation process on layer 1. The waller beam installation work itself began in early August 2024 and is expected to be completed by the end of 2024.

The object material in this study is a waller beam, known as an H-Beam. The waller beam used in this study has a dimension of 4 meters. In addition, supporting materials in the installation of waller beam units include bolts, anchor shear connectors, and chemical shear connectors. Data was collected at various stages of the work, including mobilization, marking, drilling, and several other stages.

Despite its advantages in improving data accuracy, the video recording method also has some disadvantages. The cost of procurement and implementation is relatively expensive, and the angle of view of the resulting video may be limited depending on the placement of the camera, image quality, and angle of capture. This study utilizes the Method Productivity Delay Model (MPDM) for analytical assessment (Brown, 2020). The data that has been obtained through this method is then entered into the Production Cycle Delay Sampling (PCDS) table to analyze the duration of one work cycle in conditions with or without delays (K. N. R. Putri et al., 2018; Wenas et al., 2023). MPDM is used to calculate productivity based on various factors that cause delays, such as management, labor, equipment, environment, and materials.

Data collection technique or observation is the collection of data through observing an object, person, or phenomenon and recording it systematically. The data collection methods used were time studies and MPDM. These methods ensure accurate and systematic data recording, allowing for a thorough analysis of work performance and efficiency.

The results of the productivity analysis and identification of the types of delays are then discussed to obtain relevant conclusions. The research data that has been collected, both from primary and secondary sources, is analyzed to estimate the duration of work execution and formulate productivity improvement measures. The conclusion of this research is expected to provide a concrete solution to improve labor efficiency in the waller beam installation work.

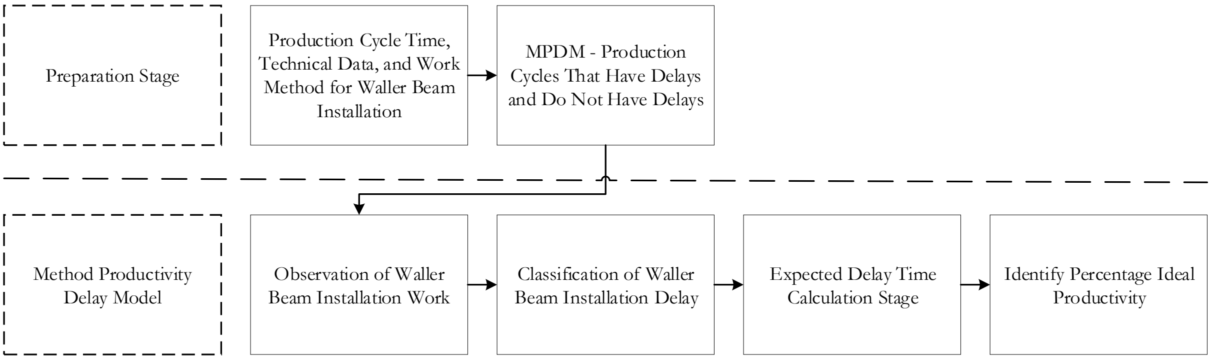

Figure 1. Research Conceptual Framework Method Productivity Delay Model

The conceptual framework of the study is shown in Figure 1 in indentify the productivity of waller beam installation. The process starts from the Preparation Stage, which includes collecting production cycle data, technical data, and work methods. This data is then used to identify production cycles that experience delays and those that do not experience delays. The next step is direct observation of the waller beam installation work to classify the types of delays that occur during the production process.

After the classification of delays is done, the next step is the calculation of the expected delay time, which aims to measure the extent to which delays affect productivity. The data obtained is used to calculate actual productivity compared to ideal productivity, so that the level of work efficiency can be determined. With this approach, the MPDM method enables the identification of factors causing delays and provides a basis for improvement efforts in the management of construction project labor and resources.

Research Results and Discussion

Data collection in this study was carried out by observing the waller beam installation work and recording the time required to complete one work cycle. This time recording starts from the first stage of a cycle until the completion of the cycle. 1 cycle is when the installed waller beam reaches 1 unit. The sequence of work for 1 cycle is as follows:

1. Mobilization of Waller Beam from Workshop to Site;
2. Positioning of the Waller Beam on to the Bracket;
3. Joining of Waller Beam;
4. Marking of D-Wall Shear Connector;
5. Displacement of Waller Beam in Facilitating Drilling of Shear Connector;
6. Drilling of Anchor Shear Connector;
7. Chemical Anchor Shear Connector;
8. Displacement of Waller Beam to be bonded with Shear Connector;
9. Shear Connector bolting.

The sample size in this study was 47 units, where each unit represented one work cycle consisting of nine stages. Each cycle is worked on by a team of nine people, who carry out all stages of the work sequentially until completion before moving on to the next unit or point. The specially selected team only carried out the waller beam works, excluding strutting works and other retaining wall elements, with the aim of maintaining consistency of implementation and evaluation results in each work cycle.

The recording of one work cycle starts from the first stage to the ninth stage, which is carried out repeatedly until the installation of one unit of waller beam is completed. Observations and data collection were conducted on Construction Project X in South Jakarta for 90 working days. During this period, observations and recordings were made of a team of workers in charge of installing waller beams in layer 1 to layer 3 in the project. The recordings obtained were then processed into data as described in Table 1. After processing, the results were obtained in the form of overall productivity and ideal productivity, as well as information on the factors of delay in waller beam installation work.

Table 1. Production Cycle Delay Sampling

Production Cycle	Production Cycle Time	Environ-mental Delay	Equip-ment Delay	Material Delay	Manage-ment Delay	Labour Delay	Information	Non Delay Cycle Time	Minus Mean Non Delay Cycle Time	Non Delay Production Cycle Time
	Second	Second	Second	Second	Second	Second		Second	Second	Second
1	2056.72			51.63			Delay	2005.09	16.02	67.65
2	2084.44					127.48	Delay	1956.96	11.70	115.78
3	1984.61						Non Delay	1984.61	88.13	88.13
4	1998.47						Non Delay	1998.47	74.27	74.27
5	2101.74						Non Delay	2101.74	29.00	29.00
…										
…										
47	2050.98						Non Delay	2050.98	21.76	21.76
Total Durasi	113890.31	4401.34	4851.03	1332.25	379.86	5506.82				
Mean Non Delay Cycle Time									2072.74	
Total Non Delay Production Cycle Time				97419.01			Total Minus Mean Non Delay Cycle Time			998.07
Mean Non Delay Production Cycle Time				2072.74			Mean Minus Mean Non Delay Cycle Time			47.53
Total Overall Production Cycle Time				113890.31			Total Minus Mean Non Delay Cycle Time (Overall)			16800.84
Mean Delay Production Cycle Time				2423.20			Mean Minus Mean Non Delay Cycle Time (Overall)			646.80

Based on the results of the Production Cycle Delay Sampling analysis in Table 1, this study identified delays in 47 waller beam installation production cycles by grouping the delay factors into five main categories, including environmental, equipment, labor, material, and management factors. The data shows that the labor factor is the biggest cause of delay with a total delay duration of 5506.82 seconds, followed by the equipment factor of 4851.03 seconds. The delay caused by material, environment, and management recorded a total duration of 1332.25 seconds, 4401.34 seconds, and 379.86 seconds, correspondingly.

In some production cycles, there are delays caused by various factors. For example, in the first cycle, there was a material delay of 51.63 seconds, causing the production cycle time to be 2056.72 seconds, while the non-delay cycle time for this cycle was 2005.09 seconds, with a difference of 16.02 seconds from the average non-delay cycle time. The same thing happened in the second cycle, where the delay due to labor of 127.48 seconds caused the total production time to be 2084.44 seconds, with a non-delay time of 1956.96 seconds and a difference of 115.78 seconds from the average non-delay time.

However, some production cycles recorded non-delays, as seen in the third, fourth, and fifth cycles. The production times recorded in these cycles are the same as the non-delay times, with 1984.61 seconds, 1998.47 seconds, and 2101.74 seconds performed respectively. This shows that production can run more stably and closer to the ideal cycle time under optimal conditions without constraints.

The Mean Non-Delay Cycle Time was calculated to be 2072.74 seconds. This indicates that if the delay factor can be minimized, then production efficiency can be improved by keeping the production cycle time close to or below this figure. This analysis confirms that labor delay is the dominant factor in affecting productivity, so a strategy to improve labor efficiency is needed to reduce the overall production cycle time.

In addition to identifying the main factors causing delays, the data also showed that the total production cycle time without delays was 97419.01 seconds. The average cycle time without delays was calculated at 2072.74 seconds per cycle. When compared to the overall total production cycle time of 113890.31 seconds, it can be concluded that delays have a significant impact on increasing the total work duration, with an additional time of 16800.84 seconds from the entire observed cycle.

Another example, the average production cycle time with delays was calculated to be 2423.20 seconds. This value indicates that each delayed cycle has a duration of 646.80 seconds longer than the average cycle time without delays. This confirms that delays in production have a considerable impact on overall project efficiency. This research emphasizes the importance of optimizing work processes, especially in overcoming inefficiencies related to labor. The labor factor caused the greatest delay with a total duration of 5506.82 seconds, followed by the equipment factor which reached 4851.03 seconds. By improving labor management as well as equipment availability, the production cycle time can be closer to the ideal cycle time without delays, thus productivity increases and the overall project duration can be reduced.

Table 2. MPDM Processing

Unit	Total Production Cycle Time	Production Cycles (n)	Non Delay Production Cycle (n)	Mean Cycle Times	$\Sigma(\lvert(\text{Cycle Time})-(\text{Non Delay Cycle Time})\rvert)/n$
Non Delay Production Cycle	97419.01	47	21	2072.74	49.90
Overall Production Cycle	11389.31	47		2423.20	379.04

Based on Table 2 MPDM Processing, it can be seen that the total production cycle time without delay (Non Delay Production Cycle) reaches 97419.01 seconds and the total production cycle time (Overall Production Cycle) reaches 113890.31 seconds with a total of 47 production cycles. Of the total 47 cycles observed, only 21 cycles fall into the category of no delay, while the rest experience various delay factors. The average production cycle time without delays was calculated at 2072.74 seconds, while the average Overall Production Cycle time reached 2423.20 seconds, which means there is a difference in average time of 350.46 seconds per cycle due to delays in production.

The difference in average time between the production cycle without delays and the overall production cycle shows that delays have a significant effect on production efficiency. The variation of production time due to delays in the cycle without bottlenecks is about 49.90 seconds, while in the overall production cycle, the variation is much larger, about 379.04 seconds. This indicates that the instability of production time increases drastically when the delay factor occurs, thus affecting the overall productivity. The significant difference between the production cycle without delays and the overall production cycle indicates the potential for efficiency improvements if delays can be minimized. By understanding the most influential factors causing delays, corrective measures can be better focused on improving the stability of the production cycle. This will have an impact on improving overall productivity and optimizing the use of time in the production process.

Table 3. Delay Information

	Delay				
	Environmental	Equipment	Material	Management	Labour
C) Occurrences	2	10	7	1	17
D) Total added time	4401.34	4851.03	1332.25	379.86	5506.82
E) Probability of occurrence	0.04	0.21	0.15	0.02	0.36
F) Relative severity (D : (C x Mean Overall)	0.91	0.20	0.08	0.16	0.13
G) Expected % delay time per production cycle (E x F) = Percentage Waste	3.86%	4.26%	1.17%	0.33%	4.84%

Based on Table 3 Delay Information, delays in the production cycle are influenced by five main factors, which are environment, equipment, material, management, and labor. Of the overall data, the labor factor has the highest number of delays, which is 17 times, with a total delay time of 5506.82 seconds and an occurrence probability of 0.36. This factor is the main cause of delays in production. The equipment factor is in second place with 10 occurrences and a total delay time of 4851.03 seconds, with a probability of 0.21. Material factors experienced delays 7 times with a total delay time of 1332.25 seconds and a probability of occurrence of 0.15 while management factors only experienced 1 delay event with a total delay time of 379.86 seconds and a probability of 0.02. However, environmental factors, although only occurring twice, have a considerable total delay time of 4401.34 seconds, with a probability of 0.04. This indicates that delays due to environmental factors may be rare, but when they do occur, they have a significant impact on production.

Regarding relative severity, the environmental factor has the highest severity of 0.91 indicating that despite its low frequency, its impact on production is substantial. The management factor has a relative severity of 0.16 indicating that although it occurs infrequently, the effect is still worth noting. The equipment factor has a severity of 0.20, followed by the labor factor at 0.13 and the material factor with the lowest severity of 0.08. These relative severity values indicate that environmental and management factors have a more significant impact on production delays compared to other factors. Percentage-wise, the labor factor has the highest rate of 4.84%, followed by equipment at 4.26%. Environmental factors also have a sizable percentage of delay at 3.86%, while material and management factors have percentages of 1.17% and 0.33%, respectively. These results suggest that workforce optimization, better equipment maintenance, and mitigation of environmental impacts can be key strategies in reducing delays and improving overall production efficiency.

Table 4. Calculation of Productivity of Waller Beam Installation Work

Total Expect % Delay Time per Period Cycle	14.46%
Ideal Productivity (units/s)	1.737
Overall Productivity (units/s)	1.486

% Achieved Productivity based on Ideal Productivity	85.54%
Ideal Cycle Variability	0.02
Overall Cycle Variability	0.156

Based on Table 4 Calculation of Productivity of Waller Beam Installation Work shows that the total percentage of expected delays per production cycle is 14.46%. Ideally, the productivity rate should reach 1.737 units per second. However, due to various delay factors, the actual productivity achieved is only 1.486 units per second. This indicates that the level of achieved productivity compared to the ideal productivity is 85.54%, highlighting the potential for increased efficiency if delay factors can be minimized. In this context, units/s represents the number of waller beam units installed per second as a measure of work productivity.

Additionally, the fluctuation in production time should ideally be 0.02, but the actual recorded variability is significantly higher at 0.156. This suggests an inconsistency in the production cycle, likely influenced by factors such as labor efficiency, equipment readiness, and environmental conditions. To enhance productivity and reduce production cycle variability, it is essential to implement more effective improvement strategies, including optimized workforce allocation, better time management, and enhanced equipment maintenance to minimize operational disruptions.

Based on the identification results, there are several factors that affect human resource productivity in waller beam installation, namely work environment, equipment, labor, materials, and management, with delay contributions of 0.04, 0.21, 0.36, 0.15, and 0.02, respectively. Analysis using the Productivity Delay Model Method (MPDM) shows that labor delays are the main factor causing a decrease in productivity, with an overall productivity of 1.486 units/s and a productivity achievement of only 85.54% of the ideal productivity of 1.737 units/s. The findings of this study align with previous research on labor productivity in light brick wall installation for a residential project in Surabaya, which recorded an average productivity of 1.247 m² per person-hour, with observed variations between 1.125 m² and 1.344 m² per person-hour (Dwipurwanto, 2023).

The observed fluctuations in productivity indicate that construction efficiency is highly dependent on labor performance as well as the specific challenges faced in each project. The results of this study emphasize the importance of identifying the main factors causing delays and implementing appropriate improvements to optimize labor productivity in wall beam installation. Productivity calculations become more complex when there is a change in work teams, as each team has different work patterns, speeds and efficiency levels. The findings indicate that labor is the dominant factor causing delays, so innovative methods or systematic improvements in labor management are needed. One solution that can be applied is skill enhancement through training programs, to ensure productivity remains optimal and can be measured more accurately under various project conditions.

It was observed that the waller beam work contributed a progress of 85.54% to the overall work cycle in one unit, which showed significant efficiency compared to other structural elements. In comparison, lower structural works such as bored pile foundations, pile caps, and tie beams often experience progress delays due to unstable soil conditions, heavy equipment requirements, and other technical factors (Ulil Albab, 2021). This percentage difference indicates that the preparation of work schedules and resource allocation for the lower structural work needs to consider the characteristics of each element so that there is no imbalance in progress between work components. The productivity of retaining walls using strutting and ground anchor systems in the underground metro station project shows that certain reinforcement systems can provide better performance in resisting lateral deformation depending on the site context (Kalyani et al., 2021). This comparison confirms that the selection of support systems such as waller beams, strutting, or ground anchors should be tailored to the conditions and technical objectives of the project, and should be quantitatively analyzed through approaches such as MPDM to ensure the efficiency and stability of the retaining wall works.

Lean construction approaches, prefabrication, and real-time monitoring systems are modern strategies in the construction industry that aim to improve project efficiency and productivity. Lean construction focuses on minimizing delays by increasing the efficiency of work processes and improving coordination and communication between teams (Wang et al., 2022). Meanwhile, prefabrication can reduce the duration of on-site work, improve the quality of structural elements, and avoid disruptions due to weather or unexpected field conditions (Rocha et al., 2022). On the other hand, real-time monitoring technology plays an important role in providing actual data related to work progress and enabling the identification of problems quickly and precisely, so that the decision-making process can be carried out responsively (Musarat et al., 2024).

In the context of this research, the application of the MPDM to the waller beam work categorizes the causes of delay into five main factors: environmental, equipment, material, management, and labor. The use of lean construction can reduce delays stemming from management and labor by strengthening planning and communication between project departments (Bigwanto et al., 2024). Prefabrication can be a solution to material and equipment problems, as precast elements allow for more assured quality and a faster installation process (Lakhani, 2024). Meanwhile, real-time monitoring is highly relevant for detecting potential disturbances from environmental factors in real time as well as evaluating actual productivity in the field (Santos Fonseca et al., 2025). These three approaches, if applied in an integrated manner, can support the implementation of MPDM more effectively in an effort to increase productivity and control delay in waller beam work.

Conclusion

In this study, delays in waller beam installation were primarily attributed to labor inefficiencies, equipment malfunctions, environmental challenges, material shortages, and management issues. As a result, overall productivity was recorded at 1.486 units/s, achieving only 85.54% of the ideal productivity of 1.737 units/s. To mitigate these delays, strategies such as enhancing workforce training, implementing preventive maintenance programs, adopting flexible scheduling to accommodate environmental conditions, ensuring timely procurement of quality materials, and strengthening project planning and communication are recommended (Banobi & Jung, 2019). These approaches align with findings from recent studies on construction delay mitigation strategies.

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