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Application Of The Line Of Balance Method In The Scheduling Of High-Rise Building Construction In Bandung City (Case Study: UNIPI Bandung Campus Building Construction Project)

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Abstract

The construction of high-rise buildings requires effective scheduling methods to ensure project completion according to time, cost, and quality targets. This study aims to analyze the effectiveness of the Line of Balance (LOB) method compared with the Bar Chart method in scheduling structural work on the UNIPI Bandung Campus Building Construction Project. This research used a quantitative comparative method based on secondary data, including project schedules, work durations, and repetitive structural activities such as columns, beams, slabs, and stairs. The analysis was conducted by developing LOB schedules using average and minimum lag times, followed by a comparison of project duration and time efficiency. The results showed that the LOB method using minimum lag time produced the shortest duration, reducing the project completion time from 24 weeks to 20 weeks with a time efficiency of 16.67%. The total project cost remained unchanged, but the weekly cost distribution differed due to accelerated work progress. The LOB method is effective for optimizing repetitive construction scheduling and improving workflow continuity.

Keywords: ***Line of Balance, project scheduling, repetitive construction, construction management, high-rise building***

INTRODUCTION

The construction industry plays an important role in supporting economic growth and infrastructure development in Indonesia. The increasing demand for high-rise building construction requires construction projects to achieve quality, cost, and time targets simultaneously. Timely project completion is one of the main indicators of project success because delays can lead to increased costs, reduced resource productivity, and disruption of project implementation (Husen, 2011).

Project scheduling is an essential component of construction management that functions to organize activity sequences, determine work durations, and control project implementation to ensure that it proceeds according to the planned schedule. The Bar Chart method is one of the most commonly used scheduling methods in construction projects because it is simple and easy to understand. However, this method has limitations in illustrating the continuity of repetitive activities, particularly in high-rise building projects that involve repetitive work patterns (Widiasanti & Lenggogeni, 2013).

In high-rise building construction projects, structural works such as columns, beams, and floor slabs are carried out repeatedly on each building level. This condition requires a scheduling method that can effectively illustrate the relationship between time and work location. One method suitable for repetitive construction activities is the Line of Balance (LOB) method. This method is capable of representing the production rate of each activity through the relationship between time and work units, thereby facilitating the control of work continuity (Callahan et al., 1992).

The implementation of the Line of Balance method can assist in identifying work constraints, balancing activities, and reducing the possibility of conflicts between construction tasks. Unlike the Bar Chart method, which only presents the relationship between time and activities, the LOB method provides a visual representation of work movement from one unit to another, making it more suitable for projects with repetitive characteristics (Arditi et al., 2002).

Several studies have shown that the Line of Balance method can improve scheduling effectiveness in repetitive construction projects by optimizing work sequences and reducing the potential for project delays. However, the implementation of this method in high-rise building projects in Indonesia remains relatively limited because many contractors still rely on the Bar Chart method as the primary scheduling approach.

Based on these conditions, this study aims to analyze the comparison of project duration based on scheduling results using the Line of Balance method and the Bar Chart method in the construction project of the UNIPI Bandung Campus Building. This research is expected to provide information regarding the effectiveness of the Line of Balance method in producing a more optimal project duration compared to conventional scheduling methods.

RESEARCH METHODS

This research was conducted on the UNIPI Bandung Campus Building Construction Project located on Jl. Rancamalang, Margaasih Village, Margaasih District, West Bandung Regency. This study employed a comparative study method with a quantitative approach to compare the existing project scheduling using the Bar Chart method with the scheduling results obtained using the Line of Balance (LOB) method. The quantitative approach was applied because the analysis was based on numerical data, including work durations and activity sequences. The population in this study consisted of all activities within the high-rise building construction project in Bandung, while the data sampling technique used was purposive sampling by selecting repetitive work activities that were relevant for analysis using the LOB method.

The data used in this study were secondary data obtained from project documents, including existing scheduling data using the Bar Chart method, work durations, and work weight data as the basis for cost analysis. Data validation was carried out through confirmation with the project team of the UNIPI Bandung Campus Building Construction Project to ensure that the data used were consistent with actual field conditions. Data processing was performed by identifying repetitive activities, analyzing activity dependencies, determining lead time, lag time, and buffer time, and then developing a revised project schedule using the Line of Balance (LOB) method. The scheduling results were subsequently compared with the Bar Chart method to determine the difference in project duration. The research stages included data collection, identification of repetitive activities, preparation of the Line of Balance diagram, comparative analysis of project duration, and formulation of conclusions based on the research findings.

RESULTS AND DISCUSSION

Line of Balance Pekerjaan Struktur Berdasarkan Durasi Barchart

The implementation of the *Line of Balance (LOB)* method in structural work aims to optimize the scheduling of repetitive activities, such as column construction on each floor. Based on the initial Bar Chart scheduling, the work sequence and duration of each activity were analyzed as the basis for developing the Line of Balance sched

Column

Table 1. Column Work Duration and Lag Time Based on Bar Chart Duration

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time	Lag Duration
1	C.1.1	1st Floor Column	5	11	7	-	-
2	C.2.1	2nd Floor Column	7	13	7	1-SS-2 Lag 2	2
3	C.3.1	3rd Floor Column	10	14	5	2-SS-3 Lag 3	3
4	C.4.1	4th Floor Column	12	16	5	3-SS-4 Lag 2	2
5	C.5.1	5th Floor Column	14	18	5	4-SS-5 Lag 2	2
6	C.6.1	Roof/Dak Floor Column	15	19	5	5-SS-6 Lag 1	1
		Average Lag Time					2
		Minimum Lag Time					1

Source: Analysis Results, 2026

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Based on Table 1, the column work has an average *lag time* of 2 weeks and a minimum *lag time* of 1 week. These values indicate the existence of time intervals between column activities on each floor before the subsequent work activity begins.

Beam and Slab Work

Table 2. Beam and Slab Work Duration and Lag Time Based on Bar Chart Duration

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time	Lag Duration
1	C.1.2	1st Floor Beam and Slab	6	13	8	-	-
2	C.2.2	2nd Floor Beam and Slab	8	15	8	1-SS-2 Lag 2	2
3	C.3.2	3rd Floor Beam and Slab	11	16	6	2-SS-3 Lag 3	3
4	C.4.2	4th Floor Beam and Slab	13	18	6	3-SS-4 Lag 2	2
5	C.5.2	5th Floor Beam and Slab	15	20	6	4-SS-5 Lag 2	2
6	C.6.2	Roof/Dak Floor Beam and Slab	19	24	6	5-SS-6 Lag 4	4
		Average Lag Time					3.2
		Minimum Lag Time					1

Source: Analysis Results, 2026

Based on Table 2, the beam and slab work has an average *lag time* of 3.2 weeks and a minimum *lag time* of 1 week. These values indicate the time intervals between beam and slab activities on each floor before the next activity begins. The variation in *lag time* is influenced by the differences in work duration and the continuity requirements between structural activities on each building level.

Stair Structure Work

Table 3. Stair Structure Work Duration and Lag Time Based on Bar Chart Duration

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time	Lag Duration
1	C.1.3	1st Floor Stair	13	13	1	-	-
2	C.2.3	2nd Floor Stair	17	17	1	1-SS-2 Lag 4	4
3	C.3.3	3rd Floor Stair	18	18	1	2-SS-3 Lag 1	1
4	C.4.3	4th Floor Stair	19	19	1	3-SS-4 Lag 1	1
5	C.5.3	5th Floor Stair	21	21	1	4-SS-5 Lag 1	1
		Average Lag Time					2
		Minimum Lag Time					1

Source: Analysis Results, 2026

Based on Table 3, the stair structure work has an average *lag time* of 2 weeks and a minimum *lag time* of 1 week. These values indicate the time intervals between stair construction activities on each floor before the subsequent activity begins. The applied *lag time* is used to maintain the continuity and sequence of repetitive structural work throughout the building levels.

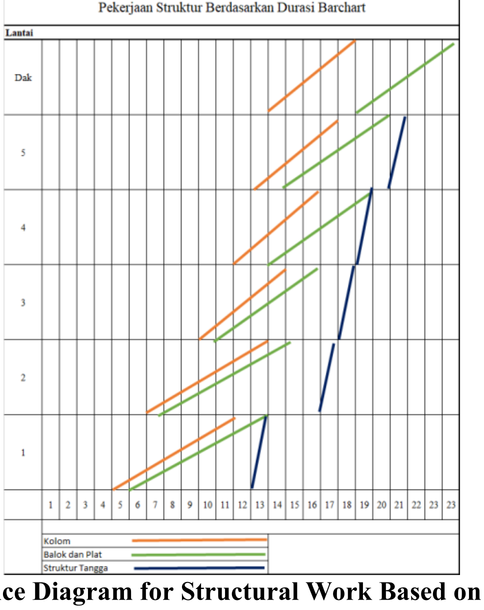

Figure 1 Line of Balance Diagram for Structural Work Based on Bar Chart Duration

Based on the Line of Balance (LOB) diagram, the sequence of structural work implementation has been arranged logically, starting with column work, followed by beam and slab work, and completed with stair structure work on each floor. This sequence is in accordance with the construction stages of high-rise buildings, where beam and slab activities can only be carried out after the columns have reached the required condition, while stair structure work is performed after the main structural elements on each floor have been completed.

Line of Balance for Structural Work Based on Average Lag Time

In this section, the Line of Balance (LOB) scheduling was adjusted using the average *lag time* value obtained from the previous analysis. The adjustment of the *lag time* value into a uniform interval aims to create a more regular and balanced work rhythm between floors for each structural work item.

Column

Table 4. Column Work Based on Average Lag Time

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time
1	C.1.1	1st Floor Column	5	11	7	-
2	C.2.1	2nd Floor Column	7	13	7	1-SS-2 Lag 2
3	C.3.1	3rd Floor Column	9	13	5	2-SS-3 Lag 2
4	C.4.1	4th Floor Column	11	15	5	3-SS-4 Lag 2
5	C.5.1	5th Floor Column	13	17	5	4-SS-5 Lag 2
6	C.6.1	Roof/Dak Floor Column	15	19	5	5-SS-6 Lag 2

Source: Analysis Results, 2026

The implementation of an average *lag time* of 2 weeks causes the column work schedule between floors to shift consistently, resulting in a more uniform workflow pattern. This condition creates a balanced production flow in the *Line of Balance (LOB)* schedule and helps maintain continuity between repetitive structural activities.

Beam and Slab Work

Table 5. Beam and Slab Work Based on Average Lag Time

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time
1	C.1.2	1st Floor Beam and Slab	6	13	8	-
2	C.2.2	2nd Floor Beam and Slab	8.6	15.6	8	1-SS-2 Lag 2.6
3	C.3.2	3rd Floor Beam and Slab	11.2	16.2	6	2-SS-3 Lag 2.6
4	C.4.2	4th Floor Beam and Slab	13.8	18.8	6	3-SS-4 Lag 2.6
5	C.5.2	5th Floor Beam and Slab	16.4	21.4	6	4-SS-5 Lag 2.6
6	C.6.2	Roof/Dak Floor Beam and Slab	19	24	6	5-SS-6 Lag 2.6

Source: Analysis Results, 2026

By applying an average *lag time* of 2.6 weeks, the interval of beam and slab work progression from lower floors to upper floors becomes more consistent and structured. This adjustment creates a more balanced workflow pattern and improves continuity between repetitive structural activities within the Line of Balance (LOB) schedule.

Stair Structure Work

Table 6. Stair Structure Work Based on Average Lag Time

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time
1	C.1.3	1st Floor Stair	13	13	1	-
2	C.2.3	2nd Floor Stair	15	15	1	1-SS-2 Lag 2
3	C.3.3	3rd Floor Stair	17	17	1	2-SS-3 Lag 2
4	C.4.3	4th Floor Stair	19	19	1	3-SS-4 Lag 2
5	C.5.3	5th Floor Stair	21	21	1	4-SS-5 Lag 2

Source: Analysis Results, 2026

The application of an average *lag time* of 2 weeks provides a consistent interval for stair construction activities on each floor. This adjustment creates a more regular work sequence and maintains continuity between repetitive stair structure activities. The Line of Balance (LOB) diagram for stair structure work based on the average *lag time* is presented in the following figure.

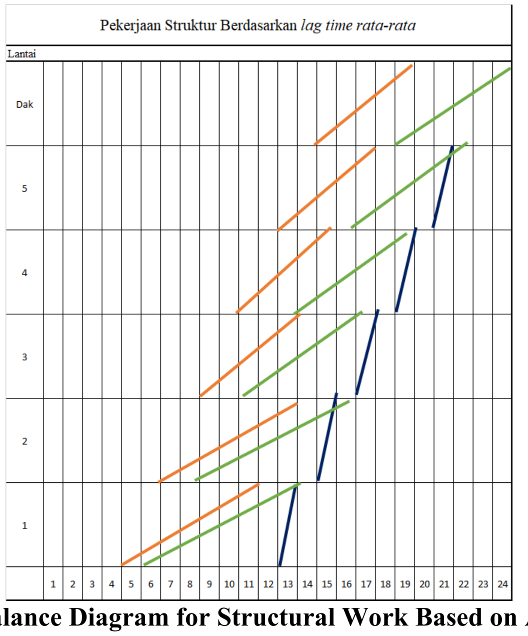

Figure 2 Line of Balance Diagram for Structural Work Based on Average Lag Time

Based on the Line of Balance (LOB) diagram using the average *lag time*, structural works consisting of columns, beams and slabs, and stair structures show a more organized implementation pattern compared to the Bar Chart-based scheduling. The time intervals between activities on each floor become more consistent, allowing the transition of work from one floor to the next to proceed with a relatively uniform production rhythm.

Line of Balance for Structural Work Based on Minimum Lag Time

In this section, the Line of Balance (LOB) scheduling was adjusted using the minimum *lag time* value obtained from the initial scheduling analysis. The application of the minimum *lag time* aims to reduce the time intervals between repetitive activities on different floors so that the project duration can be optimized and completed in a shorter period.

Column

Table 8. Column Work Based on Minimum Lag Time

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time
1	C.1.1	1st Floor Column	5	11	7	-
2	C.2.1	2nd Floor Column	6	12	7	1-SS-2 Lag 1
3	C.3.1	3rd Floor Column	7	11	5	2-SS-3 Lag 1
4	C.4.1	4th Floor Column	8	12	5	3-SS-4 Lag 1
5	C.5.1	5th Floor Column	9	13	5	4-SS-5 Lag 1
6	C.6.1	Roof/Dak Floor Column	10	14	5	5-SS-6 Lag 1

Source: Analysis Results, 2026

The application of a minimum *lag time* of 1 week accelerates the starting time of column activities on the upper floors significantly, allowing the entire column work sequence to be completed earlier.

Beam and Slab Work

Table 9. Beam and Slab Work Based on Minimum Lag Time

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time	Lag Duration
1	C.1.2	1st Floor Beam and Slab	2	10	8	-	1
2	C.2.2	2nd Floor Beam and Slab	3	12	9	1-SS-2 Lag 1	1
3	C.3.2	3rd Floor Beam and Slab	4	10	6	2-SS-3 Lag 1	1
4	C.4.2	4th Floor Beam and Slab	5	11	6	3-SS-4 Lag 1	1
5	C.5.2	5th Floor Beam and Slab	6	12	6	4-SS-5 Lag 1	1
6	C.6.2	Roof/Dak Floor Beam and Slab	7	12	5	5-SS-6 Lag 1	1

Source: Analysis Results, 2026

The use of a minimum *lag time* of 1 week creates a tighter and more continuous workflow pattern for beam and slab activities. This condition reduces the interval between floors, allowing the Roof/Dak Floor beam and slab work to be completed by week 12.

Stair Structure Work

Table 10. Stair Structure Work Based on Minimum Lag Time

No.	Code	Work Description	Start	Finish	Duration (Weeks)	Lag Time
1	C.1.3	1st Floor Stair	13	13	1	-
2	C.2.3	2nd Floor Stair	14	14	1	1-SS-2 Lag 1
3	C.3.3	3rd Floor Stair	15	15	1	2-SS-3 Lag 1
4	C.4.3	4th Floor Stair	16	16	1	3-SS-4 Lag 1
5	C.5.3	5th Floor Stair	17	17	1	4-SS-5 Lag 1

Source: Analysis Results, 2026

Based on Table 10, the application of a minimum *lag time* of 1 week results in a shorter interval between stair construction activities on each floor. The stair work progresses sequentially from the 1st Floor to the 5th Floor with a consistent one-week shift between activities. This condition creates a more continuous workflow pattern and minimizes idle time between repetitive stair structure activities. The use of minimum *lag time* allows the stair construction sequence to be completed faster while maintaining the planned activity relationship between floors.

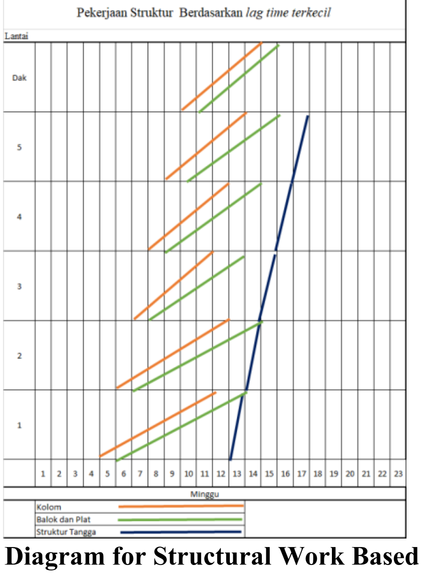

Figure 3 Line of Balance Diagram for Structural Work Based on Minimum Lag Time

Based on the Line of Balance (LOB) diagram using the minimum *lag time*, structural works consisting of columns, beams and slabs, and stair structures show a more accelerated workflow pattern compared to the scheduling based on average *lag time* and Bar Chart duration. The smaller interval between activities allows the transition of work from one floor to the next to occur faster and more continuously.

Conflict and Buffer

Conflict

Table 11. Conflicts in the LOB Diagram Based on Bar Chart Duration

No.	Work Description	Conflict	Conflict No.	Conflict Analysis
1	Beam and Slab Work on 2nd Floor (C.2.2)	Stair Structure Work on 2nd Floor (C.3.2)	1	In week 13, C.2.2 and C.3.2 intersect because the production rate of C.3.2 is higher.
2	Beam and Slab Work on 4th Floor (C.2.4)	Stair Structure Work on 4th Floor (C.3.4)	2	In week 19, C.2.4 and C.3.4 intersect because the production rate of C.3.4 is higher.

Source: Analysis Results, 2026

Table 12. Conflicts in the LOB Diagram Based on Average Lag Time

No.	Work Description	Conflict	Conflict No.	Conflict Analysis
1	Beam and Slab Work on 1st Floor (C.2.1)	Stair Structure Work on 1st Floor (C.3.1)	1	In week 13, C.2.1 and C.3.1 intersect because the production rate of C.3.1 is higher.
2	Beam and Slab Work on 2nd Floor (C.2.2)	Stair Structure Work on 2nd Floor (C.3.2)	2	In week 15, C.2.2 and C.3.2 intersect because the production rate of C.3.2 is higher.
3	Beam and Slab Work on 5th Floor (C.2.5)	Stair Structure Work on 5th Floor (C.3.5)	3	In week 21, C.2.5 and C.3.5 intersect because the production rate of C.3.5 is higher.

Source: Analysis Results, 2026

Table 13. Conflicts in the LOB Diagram Based on Minimum Lag Time

No.	Work Description	Conflict	Conflict No.	Conflict Analysis
1	Column Work on 2nd Floor (C.1.2)	Column Work on 3rd Floor (C.1.3)	1	In week 11, C.1.3 overtakes the completion of C.1.2 because its production rate is higher.
2	Column Work on 2nd Floor (C.1.2)	Column Work on 4th Floor (C.1.4)	2	In week 12, C.1.4 overtakes the completion of C.1.2 because its production rate is higher.
3	Beam and Slab Work on 2nd Floor (C.2.2)	Column Work on 3rd Floor (C.1.3)	3	In week 11, C.1.3 overtakes the completion of C.2.2 because its production rate is higher.
4	Beam and Slab Work on 2nd Floor (C.2.2)	Column Work on 4th Floor (C.1.4)	4	In week 12, C.1.4 overtakes the completion of C.2.2 because its production rate is higher.
5	Beam and Slab Work on 2nd Floor (C.2.2)	Beam and Slab Work on 3rd Floor (C.2.3)	5	In week 13, C.2.3 overtakes the completion of C.2.2 because its production rate is higher.
6	Beam and Slab Work on 2nd Floor (C.2.2)	Beam and Slab Work on 4th Floor (C.2.4)	6	In week 14, C.2.4 overtakes the completion of C.2.2 because its production rate is higher.
7	Beam and Slab Work on 2nd Floor (C.2.2)	Stair Structure Work on 2nd Floor (C.3.2)	7	In week 13, C.2.2 and C.3.2 intersect because the production rate of C.3.2 is higher.
8	Beam and Slab Work on 4th Floor (C.2.4)	Stair Structure Work on 4th Floor (C.3.4)	8	In week 19, C.2.4 and C.3.4 intersect because the production rate of C.3.4 is higher.

Source: Analysis Results, 2026

Buffer

Table 14. Structural Work Buffer Based on Bar Chart Duration

Work Description	Buffer Duration (Weeks)
1st Floor Stair Structure Work	1
5th Floor Stair Structure Work	1

Source: Analysis Results, 2026

Table 15. Structural Work Buffer Based on Average Lag Time

Work Description	Buffer Duration (Weeks)
1st Floor Stair Structure Work	1
2nd Floor Stair Structure Work	2
3rd Floor Stair Structure Work	1
4th Floor Stair Structure Work	2

Source: Analysis Results, 2026

Based on the data presented in the tables above, the Line of Balance (LOB) diagram was developed using the average *lag time* adjustment. The application of buffer time aims to eliminate potential conflicts by providing additional intervals between repetitive structural activities, resulting in a more balanced and continuous construction workflow.

Table 16. Recapitulation of Work Duration with Buffer

No.	Work Description	Bar Chart Duration	Average Lag Time	Minimum Lag Time
1	Structural Work	24	24	21

Source: Analysis Results, 2026

Based on Table 4.16, the work duration with buffer shows that the Line of Balance (LOB) using the minimum *lag time* produces the shortest project duration compared to the Bar Chart duration and the average *lag time* approach. Therefore, the LOB scheduling with the minimum *lag time* was selected as the final LOB schedule (*LOB Finish*) because it provides the most optimal completion duration.

After applying the Line of Balance method, the time efficiency of the proposed scheduling was calculated by comparing the initial project duration with the new duration obtained from the LOB analysis. The efficiency calculation is expressed using the following equation:

$$Efisiensi\ Waktu\ \% = \left(\frac{Waktu\ Awal - Waktu\ Baru}{Waktu\ Awal}\right) X\ 100\%$$

$$Efisiensi\ Waktu\ \% = \left(\frac{24 - 21}{24}\right) X\ 100\%$$

$$Efisiensi\ Waktu\ \% = 12.5\ \%$$

The calculation results indicate that the application of the Line of Balance method using the minimum *lag time* can reduce the project duration from 24 weeks to 21 weeks, resulting in a time efficiency of 12.5% compared to the initial Bar Chart scheduling. This shows that the LOB method is effective in optimizing repetitive structural work scheduling by reducing idle time and improving workflow continuity.

CONCLUSION

Based on the analysis and discussion, it can be concluded that the application of the Line of Balance (LOB) method in the UNIPI PERSIS Campus construction project for reinforced concrete structural work can accelerate the project duration by 3 weeks compared to the Bar Chart scheduling method. The initial project duration of 24 weeks was reduced to 21 weeks, resulting in a time efficiency of 12.5%. In terms of cost, the total project cost using the Bar Chart method and the Line of Balance method remained the same, amounting to Rp24,835,131,092.60. However, differences occurred in the weekly cost distribution, where the Line of Balance method showed a significant increase in expenditure starting from the 3rd week due to the accelerated workflow.

The implementation of the Line of Balance method is recommended for construction projects with repetitive activities because it can optimize workflow continuity and improve scheduling effectiveness. Further development is suggested by utilizing specialized scheduling software to produce more accurate LOB diagrams, expanding technical references related to LOB calculations, and combining LOB with other scheduling methods through a hybrid approach to accommodate non-repetitive activities that cannot be fully represented by the LOB method.

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