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COMPARISON ANALYSIS OF LINEAR SCHEDULING METHOD (LSM) WITH PRECEDENCE DIAGRAMMING METHOD (PDM) ON DP MALL EXPANSION CONSTRUCTION PROJECT

M.Faizal Ardhiansyah, Anthonius Bara[a)], Galang Satrio and Agung Budiwirawan[1]

[1]*Civil Engineering, Faculty of Engineering, Semarang State University, Semarang City, Indonesia;*

[a)]Correspondence: anthoniusbara@students.unnes.ac.id

Abstract. The objective of this study is to analyze the comparison between the Linear Scheduling Method (LSM) and the Precedence Diagramming Method (PDM) in the DP Mall Expansion Project. The main focus of the research is to compare time efficiency, labor cost, and productivity in supporting construction with repetitive tasks. Project scheduling plays a crucial role in construction project development. In the construction industry, more focused scheduling is required for specific types of projects. This study uses a quantitative approach, specifically descriptive-comparative, to compare and analyze project scheduling using the Linear Scheduling Method (LSM) and the Precedence Diagramming Method (PDM). Scheduling analysis and preparation were carried out using Microsoft Excel and Microsoft Project. The scheduling was conducted under two scenarios: normal and accelerated. The analysis focused on architectural works, particularly regarding differences in project duration, labor wage costs, and the effectiveness of scheduling methods for repetitive work. The results show a significant difference between the two scenarios (normal and accelerated) in the Linear Scheduling Method (LSM). However, the accelerated scenario using both LSM and PDM produced the same total duration, number of workers, and labor wages due to the logical dependency relationships in PDM being applicable to LSM. LSM scheduling is more effective for repetitive work, while PDM is less effective for such projects. This research provides practical contributions for project managers in selecting the appropriate scheduling method according to the specific characteristics of a project. The results indicate that the Linear Scheduling Method (LSM) can be integrated into projects with repetitive tasks to achieve operational sustainability. This study presents a comprehensive analysis of the efficiency of scheduling methods in repetitive construction projects, contributing to project success in terms of time and cost.

Keywords : Project Scheduling, Repetitive Activity, Linear Scheduling Method (LSM), Precedence Diagramming Method (PDM)

BACKGROUND

Project management plays a crucial role in the development of construction projects. Construction projects come in various types such as tunnels, high-rise buildings, housing developments, drainage systems, highways, and others (Rzepecki & Biruk, 2018). The type of project being undertaken influences the choice of project scheduling method. Scheduling refers to the detailed allocation of time for each activity or type of work in a construction project, from the beginning of the work to the completion (Utami & Nugraheni, 2023). In the construction industry, more focused scheduling is needed, which has proven to be more suitable for specific types of projects (Yamín & Harmelink, 2001). Improper scheduling can lead to problems in construction projects, such as delays, cost overruns, and failure to meet quality standards. Cost and time control are among the most critical issues in scheduling (Michin Jr. et al., 2013 in Muhammad et al., 2017).

Proper scheduling is the key to the success of a construction project, as project success is of utmost importance (Alafeef, 2025a). A successful construction project must be completed on time, within budget, and meet the required quality standards (Alafeef, 2025b). According to Yamín & Harmelink (2001), the most commonly known and used scheduling methods in construction projects include Network Planning Diagrams, Bar Charts/Gantt Charts, and Line of Balance (LOB). The most well-known LOB methods are the Linear Scheduling Method (LSM), Productivity Scheduling Method (PSM), Vertical Production Method (VPM), and Repetitive Scheduling Method (RSM) (Rzepecki & Biruk, 2018). In practice, bar charts and S-curves are the most frequently used scheduling tools in construction projects in Indonesia (F. J. Putra, 2019). Network Planning scheduling can provide resource management results, including resource allocation and resource leveling (El-Sayegh, 2018). However, this time-based planning method is not efficient for repetitive construction projects, as it does not ensure work continuity, does not indicate the location and time where specific crews are assigned, cannot show activity progress levels, does not consider limited resource availability, and fails to provide clear and visual schedules due to redundancies in modeling repeated units (Abdallah & Alshahri, 2018; Amar, 2020; Harris & Ioannou, 1998; Luko, 2009; Mattila & Park, 2003; Yamin & Harmelink, 2001 in Monghasemi & Abdallah, 2021).

On the other hand, the Linear Scheduling Method (LSM) offers advantages such as ease in resource allocation, project progress monitoring and control, and higher efficiency in planning repetitive construction projects. LSM focuses on maximizing labor continuity by allowing workers to perform the same tasks repeatedly at different locations, completing work at one site and immediately moving to the next, thereby minimizing work disruptions (Hyari & El-Rayes, 2006).

However, selecting and applying the appropriate scheduling method in construction projects is not straightforward, as each method has its own strengths and weaknesses. Common scheduling issues include efficient resource allocation, project deadline control, and aligning the characteristics of the scheduling method with project conditions. Project delays can lead to extended completion times, increased costs, and compromised quality and safety (González et al., 2013 in Venkatesh & Venkatesan, 2017). One of the most frequently used methods is the Gantt Chart (Rolfsen & Merschbrock, 2016), but it lacks clarity and efficiency in presentation. Therefore, more specific scheduling methods are needed to address such issues, such as the Linear Scheduling Method (LSM), which emphasizes work flow, or the Precedence Diagramming Method (PDM), which details the logical relationships between activities.

Various analyses of scheduling using LSM and PDM have been conducted in several countries such as the United States (Su & Lucko, 2016), Egypt (Mohamed et al., 2023), and India (Ramani et al., 2022). In Indonesia, similar studies have also been conducted—for example, Mi'raji et al. (2023) compared the effectiveness of LOB and PDM in high-rise building projects and found that LOB was more effective for repetitive work. Another study by Astawa et al. (2020) also supports this, showing that LOB resulted in a faster completion time of 143 days compared to PDM, which took 150 days. However, there is still a gap, as these studies were conducted on small-scale projects and focused solely on duration. These studies form the basis for a more in-depth analysis in this research.

The main objective of this study is to apply LSM in repetitive construction projects and compare it with PDM scheduling for the same project, focusing on labor costs and project duration under two scenarios: normal and accelerated. The DP Mall Expansion building project was selected as a case study, using LSM and PDM as the scheduling methods. The outcomes of both methods were compared in terms of total duration efficiency and labor costs. The results of this study are expected to provide practical recommendations for project managers in selecting the most appropriate scheduling method, thereby enabling more effective labor costs and project durations while minimizing the risk of delays in construction projects.

LITERATURE REVIEW

In the implementation of a construction project, there are numerous activities involved. The execution of a project requires an appropriate project management system to ensure that the project proceeds according to plan. Project management is the process of planning, scheduling, and controlling a project within a certain period, with a specified cost, desired quality, and in accordance with the available resources (Ammar, 2020). The goal of project management is to manage and coordinate the construction process to achieve optimal results in terms of cost, time, and quality. According to Konior & Szóstak (2020), project management consists of several phases: planning, organizing, implementation, monitoring, and closing. Belferik et al. (2023) state that key characteristics of project management include clear objectives, limited time, constrained resources, risks that must be managed, and the ability to be flexible and adaptive to change.

Scheduling is a key element in construction project management (Nisar & Halim, 2018). Project scheduling is a component of project planning that includes the steps of project control and progress in terms of resource performance—namely cost, labor, equipment, and materials—so that the work can be executed and completed as scheduled (Fahrian et al., 2021). Proper planning allows project activities to begin and end on time, minimizing costs and meeting quality standards. Constraints in project time, cost, or resource availability often lead to inadequate scheduling (García-Nieves et al., 2019). Scheduling typically includes a breakdown of work types, duration of each task, start and finish times, and the interdependencies among tasks. Accelerating the completion time of a project refers to efforts to finish the project earlier than under normal scheduling conditions (I. K. A. A. Putra et al., 2020). The objective of project acceleration is to reduce activity duration. This is done under the assumption that resources are not a constraint, although it will result in increased costs. Duration estimation involves determining the number of work periods required for each activity (Riau et al., 2024).

The **Precedence Diagram Method (PDM)** is a type of network planning scheduling known as Activity on Node (AON). According to Ren & Li (2023), PDM—also referred to as node diagrams or single-arrow network diagrams—is a scheduling technique that uses nodes to represent activities and arrows to indicate logical relationships between them (Srisungnoen & Vatanawood, 2018). In the PDM system, the completion of one activity leads to the start of the next. If the preceding activity is not completed, the subsequent activity cannot begin, which may cause delays in project completion. PDM is considered more flexible than PERT/CPM for large-scale projects (Nisar & Halim, 2018) because it does not require dummy activities. As a result, logical relationships between work items can be created with overlaps without adding more activities (Romadhona et al., 2021).

Duffy et al., as cited in Ramani et al. (2022), explain that the **Linear Scheduling Method (LSM)** is a graphical technique used for time scheduling in projects with repetitive or continuous activities, such as road construction, tunnels, pipeline installations, and others. Linear scheduling is often prepared manually using Microsoft Excel. Other software tools that can be used for LSM include Vito Schedule Planner, TCM Planner, TILOS, DynaRoad, and more (Scala et al., 2023). In LSM scheduling, Microsoft Excel is used to calculate duration, start date, finish date, and buffer time (Salama et al., 2020). According to Chrzanowski and Johnston in Su & Lucko (2016), in LSM, repetitive activities are plotted as lines with constant or variable slopes across two axes—distance/location and time. The placement of these axes depends on the type of project. For linear horizontal projects such as road construction, the horizontal axis represents distance or location, while the vertical axis represents time.

METHOD

This study employs a quantitative approach with a descriptive-comparative method to compare and analyze project scheduling between the Linear Scheduling Method (LSM) and the Precedence Diagramming Method (PDM). The object of the study is the DP Mall Expansion Project in Semarang, Central Java, conducted from January to July 2024. The variables examined are time and labor costs under both normal and accelerated scheduling scenarios. The research population includes all activities and labor involved in the architectural work of the project. The project was selected as the sample due to its 16 floors and complex activities, making it highly relevant for evaluating the effectiveness of the two scheduling methods.

RESEARCH RESULTS

According to Su & Lucko (2016), in Linear Scheduling Method (LSM), repetitive activities are plotted as lines with either constant or varying slopes on two axes: distance/location and time. In linear scheduling, Microsoft Excel is used to calculate duration, start date, finish date, and buffer time (Salama et al., 2021). LSM offers several advantages, including the ability to display constraints, productivity rates, and work crew locations (Tang et al., 2018), which helps project managers monitor project workflows more effectively.

To analyze scheduling using the Linear Scheduling Method (LSM), the following steps are involved:

1. Determine the logical relationships between activities
2. Calculate the LSM variables
3. Graph the calculation results
4. Apply delays or accelerations if any preceding work is affected

Work Sequence Logic and Activity Data

The data obtained from the project team is secondary data in the form of an S-curve schedule, which includes types of work and their respective durations. Based on the S-curve, the number of workers needed is calculated using the labor coefficient from the Unit Price Analysis (AHSP) Regulation No. 1 of 2022.

Linear Scheduling Method Variables

1. Calculate the working time for each activity per floor (t)
Example: Basement wall construction

- Duration = 45 days
- Volume = 2246.88 m²
- Daily Productivity = Volume / Duration = 2246.88 / 45 = 49.93 m²/day

2. Estimate the number of work crews for all activity items (H)

- H = 4 crews
Therefore, across 16 floors, there are four floors for each crew, applying a Finish to Start (FS) relationship among work items with the same crew.

3. Calculate the total number of workers per crew based on each work item (n)
The number of workers for each item varies, as each work item has different durations and crew requirements.

- *n = number of workers per work item*

Figure 1

Linear Scheduling Method Diagram

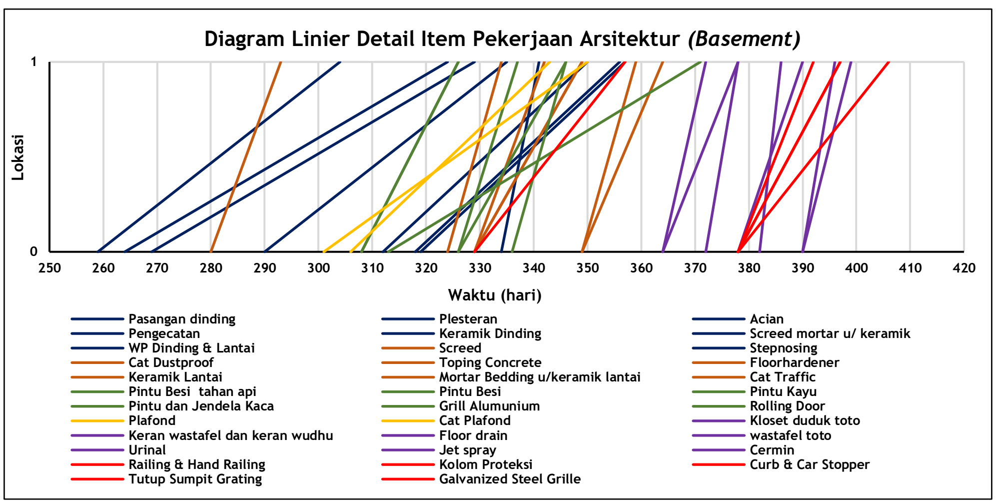
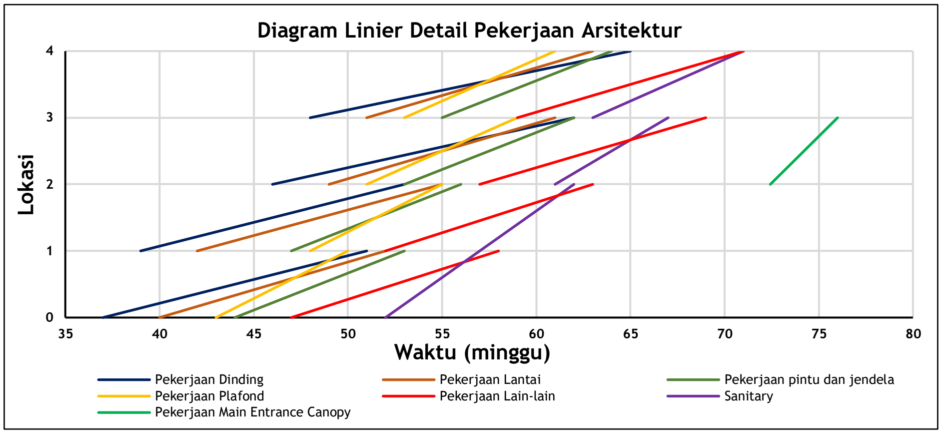


Figure 2 is based on the existing S-curve. The diagram indicates that activities on the basement floor overlap or precede one another. This occurs due to differences in the duration of each task. In Linear Scheduling Method (LSM), the sequence of activities must not intersect—meaning tasks should not disrupt or precede others (predecessors). In other words, the progress of a succeeding activity must not overtake the progress of its predecessor. To address this issue, delay and acceleration trials are carried out by considering the logical relationships between predecessors and successors. For activities at the same location, the logical relationship used is **Start to Start**, whereas for activities at different locations but executed by the same team, the relationship used is **Finish to Start**.

Figure 2

Linear Scheduling Method Diagram with Four Team



4. Delay and Acceleration Trials

Delay and acceleration trials are conducted because some task lines intersect, indicating an absence of clear successor and predecessor relationships. Additionally, these trials are necessary to align the sequence of activities with logical relationships and to avoid conflicts during field implementation.

Figure 3

Linear Scheduling Method Diagram After Delay and Acceleration

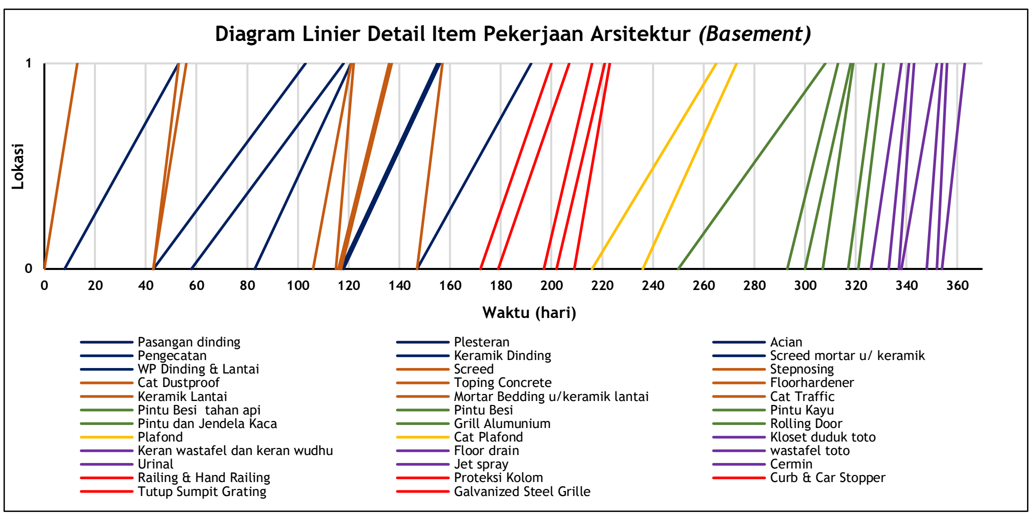
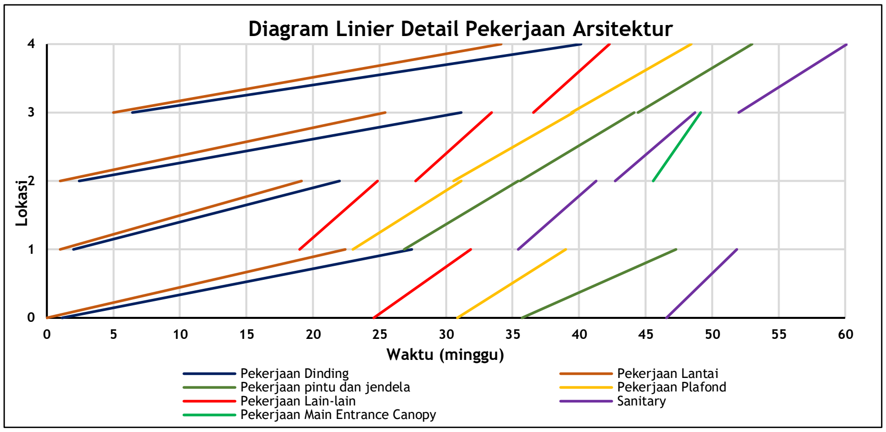


Figure 4



CONCLUSION

This study employs two different scheduling methods to plan a high-rise building construction project and compares them based on estimated duration and labor wage costs under both normal and accelerated scheduling scenarios. Using the Linear Scheduling Method (LSM), the total duration of architectural work under normal conditions is 877 days, while the accelerated schedule reduces the duration to 284 days—making it 67.61% faster than the normal schedule. Meanwhile, the total duration for the Precedence Diagramming Method (PDM) matches that of the accelerated LSM schedule.

In terms of labor requirements, the LSM under the normal schedule requires 5,803 workers, while the accelerated schedule requires 9,735 workers. Since the LSM and PDM schedules share the same duration under the accelerated scenario, the labor requirements are also identical. The difference in labor requirements leads to a variance in wage costs: the wage cost difference between the normal and accelerated LSM schedules is IDR 6,570,003,519.81. On the other hand, the labor wage cost for both LSM and PDM under the accelerated schedule is the same.

The similarity in results between the LSM and PDM methods is due to the fact that the logical dependency relationships used in PDM can also be applied within LSM, and both methods incorporate buffer time or lag between activities. PDM is effective for identifying the critical path and is well-suited for overlapping tasks; however, it lacks the ability to represent workflow constraints, productivity levels, and clear visualizations—limitations that are addressed by LSM. LSM offers advantages over PDM in terms of visual clarity, productivity tracking, depiction of workflow constraints, and more.

PENAFIAN

This article aims to provide general information about civil engineering and is not professional advice. The author and publisher are not responsible for any errors, omissions, or repercussions of the use of this information. Always consult with the relevant engineer or expert before implementing the concepts discussed.

AVAILABILITY OF DATA AND MATERIALS

The data and materials used in this article are obtained from relevant and accountable sources. However, the author does not guarantee the accuracy, completeness, or novelty of the information presented. The use of the data and materials in this article is entirely the responsibility of the reader If required, the reader may contact the author for further information regarding the availability of data and related materials.

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