MEDIA KOMUNIKASI TEKNIK SIPIL
Jurnal Ilmu dan Terapan Bidang Teknik Sipil
Website : mkts.sipil.undip.ac.id
e-ISSN : 2549 - 6778
doi: 10.14710/mkts.v30i2.63963

Analysis of Scheduling Method in Building Projects: A Case of Line of Balance and Precedence Diagram Method

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Received: 25 Mei 2024 Revised: 19 November 2024 Accepted: 20 November 2024

Abstract

The construction industry plays a significant role in a country's economic growth. However, construction projects frequently face challenges in meeting schedule targets. Project scheduling is crucial as it provides insights into enhancing the development process. Various scheduling methods are employed in construction projects, including the line of balance (LoB) method and precedence diagramming. Selecting the appropriate scheduling method impacts the project's timeline. This research aims to analyze the effectiveness of the LoB method and precedence diagramming in building construction projects, with a specific case study of a COVID center. The research method involves collecting project data, including project s-curves. The findings indicate that utilizing both the line of balance and precedence diagram methods can enhance project scheduling by ensuring the continuous allocation of resources.

Keywords: *Building construction, line of balance, precedence diagram, scheduling*

Abstrak

Industri konstruksi memainkan peran penting dalam pertumbuhan ekonomi suatu negara. Namun, proyek konstruksi sering kali menghadapi tantangan dalam memenuhi target jadwal. Penjadwalan proyek sangat penting karena memberikan wawasan untuk meningkatkan proses pembangunan. Berbagai metode penjadwalan digunakan dalam proyek konstruksi, termasuk metode line of balance (LoB) dan diagram prioritas. Pemilihan metode penjadwalan yang tepat akan mempengaruhi jadwal proyek. Penelitian ini bertujuan untuk menganalisis efektivitas metode line of balance dan precedence diagram method pada proyek konstruksi gedung, dengan studi kasus spesifik pada sebuah gedung COVID center. Metode penelitian melibatkan pengumpulan data proyek, termasuk kurva-s proyek. Hasil penelitian menunjukkan bahwa penggunaan metode line of balance dan precedence diagram dapat meningkatkan penjadwalan proyek dengan memastikan alokasi sumber daya yang berkelanjutan.

Kata kunci: *Konstruksi gedung, line of balance, precedence diagram, penjadwalan*

Introduction

This research introduces the application of two techniques in scheduling a project. Using scheduling means looking for optimization and by using two techniques, it can be compared which scheduling is more optimal, effective, and faster. Construction projects have a significant role in supporting the growth and development of development in various fields (Fei et al., 2021). The construction industry also contributes to opening up work for the community. It is directly proportional to the construction industry, which contributes to economic growth in a country (Alaloul et al., 2021).

The main challenge often faced in a construction project is scheduling problems. Project scheduling is one of the essential parts because information can be obtained related to improving the development process of a project, including resources, costs, labor, equipment, materials, and project completion time (Irsyad et al., 2022).

The project scheduling process must be able to adjust the characteristics of the project. Implementing construction projects requires a scheduling method to promptly accommodate continuous and well-scheduled resource requirements (Hartmann & Briskom, 2022).

Construction delays are referred to as prolonged construction periods beyond those previously estimated. These delays have proven to be a potential source of risk in the construction industry (Memon et al., 2023).

The stages of a construction project include planning, organizing, leading, and controlling company resources to achieve predetermined goals (Zada et al., 2023). Furthermore, project scheduling is one of the elements of planning results that can provide information about the planned schedule and project progress in terms of resource performance in the form of costs, labor, equipment, and materials, as well as project duration plans and time progress for project completion (Rakasyiwi et al., 2022). Project scheduling is allocating available time to carry out each work to complete the project to achieve optimal results by considering the existing limitations. Some commonly used scheduling methods include the line of balance and precedence diagram (Banihashemi & Khalilzadeh, 2021; Li et al., 2021).

However, considering that the scheduling method functions as a tool, its use depends on the accuracy of selecting the technique used following the type and characteristics of the planned construction project. The aspects of construction projects are simple and complex, have dependency relationships between activities, have deterministic and probabilistic time durations, and some have linear and repetitive properties (Abdelbasset et al., 2023; Parsamehr et al., 2023). It is necessary to conduct an in-depth study to examine further the scheduling with the line of balance and precedence diagram methods.

A project is a temporary effort to produce a unique product or service (Hindarto, 2023). Furthermore, in general, projects involve several interconnected people, and the main project sponsor is usually interested in effectively using resources to complete the project efficiently and on time (Sagar et al., 2022). A construction project is a series of activities to achieve a specific goal within time, cost, and quality constraints (Pan & Zhang, 2021). Construction projects require resources; material, man, machine, method, money, information, and time. The stages of implementing a construction project include the feasibility study, the construction project explanation, the design, the procurement/bidding, the implementation, maintenance, and start-up (Tariq & Gardezi, 2023).

Building projects are one type of construction project. Building buildings have different characteristics from other construction projects, such as civil buildings, including roads, bridges, dams, and other infrastructure. Some of the challenges of building work are carried out in relatively narrow locations, requiring management, especially for progressing labor intensive work and having a scope and level of building technology that is much larger and more complicated. It defines management as planning, organizing, leading, and controlling the activities of members and other resources to achieve predetermined organizational goals (Muliati et al.,2022; Verolio &Pamadi, 2023).

Project management functions as a process, management recognizes a logical sequence of implementation, which illustrates that management actions are directed at achieving predetermined goals because setting goals (objectives) is the first management action, followed by planning, organizing and coordinating, implementing, and monitoring and controlling by utilizing available resources efficiently and effectively. Management is the science and art of utilizing human resources and other resources effectively and efficiently to achieve a particular goal (Wei et al., 2024). Meanwhile, management as mobilizing people and facilities to achieve specific goals. There are three outlines discussed in project management to create the ongoing project, namely planning, scheduling, and project control. Schedule management involves planning, organizing, mobilizing, and monitoring time productivity (Simonaitis et al., 2023). Schedule management aims at productivity, which means the ratio of output to input. Planning the use of time is not a waste but provides guidance, direction, and even time supervision. The aspects of schedule management are determining project schedules, measuring and reporting on project progress, comparing scheduling with actual project progress in the field, choosing the consequences caused by comparing programs with improvement in the area at the end of project completion, planning treatments to overcome these consequences, finally updating project scheduling again (Geurtsen et al., 2023; Awali et al., 2024).

Repetitive work is a type of work that involves performing the same simple task repeatedly. These tasks are usually similar in length, the amount of strength required, or the physical action involved. Scheduling is the process of planning the allocation of resources to work on work activities at a particular time, which will then be done by sequencing work at each processing center to achieve optimality (Rehman et al., 2022). Scheduling aims to reduce the delay from the specified deadline to meet the agreed deadline with consumers. Scheduling can also increase the productivity of work equipment and minimize idle time (Kaufmann & Kock, 2022). Continuity of labor refers to the unbroken period of time that an

individual is employed by the same employer. It is a key factor in determining an employee's rights and benefits, such as: redundancy pay, notice periods, and eligibility for certain leaves. Increased productivity means less idle time, so the company can indirectly reduce production costs. The better the scheduling, the more profitable it is for the project or company, and it can be a reference for increasing profits and strategies for companies in customer satisfaction (Irawati et al., 2021; Altuwaim et al., 2024). The absence of work breaks can lead to burnout, which is a state of exhaustion that can affect an employee's physical, mental, and emotional health. Burnout can cause a decrease in motivation, increased cynicism, and reduced productivity. Furthermore, the stages of preparing a construction project schedule include defining project activities, sequencing project activities, estimating the resource requirements of project activities, estimating the duration of project activities, preparing the initial project schedule, and controlling the schedule (Simonaitis et al., 2023; Geurtsen et al., 2023).

Method

This research is based on a case study on the Covid Center Building Construction Project, Parepare. Based on the data collected, obtained project schedule data with Barchart and S Curve methods. The research operational model can be seen in Figure 1. The research begins with a formulation of the problem, then a literature review is carried out to develop theories related to scheduling using the LoB and PDM methods. Furthermore, project schedule data is collected to be processed to analyze the scheduling and then a comparative analysis of the two methods is carried out.

The data in this study are in the form of construction project planning documents made by the contractor. The data is collected using document searches. The data obtained will then be processed to obtain representative problem modeling. The methods used in this research are line of balance and precedence diagram method with the expected result is an analysis of the effectiveness of using both methods in planning construction project schedules. The resulting modeling is then applied to the project schedule, a case study to obtain a proposed optimum solution for the project planning scheme. The last step is to conclude the research results and provide suggestions and input related to the project. In this study, an analysis of project scheduling will be carried out on building projects. From the project data obtained, project rescheduling will be made using LoB and PDM. Then analyze the scheduling methods that have been made.

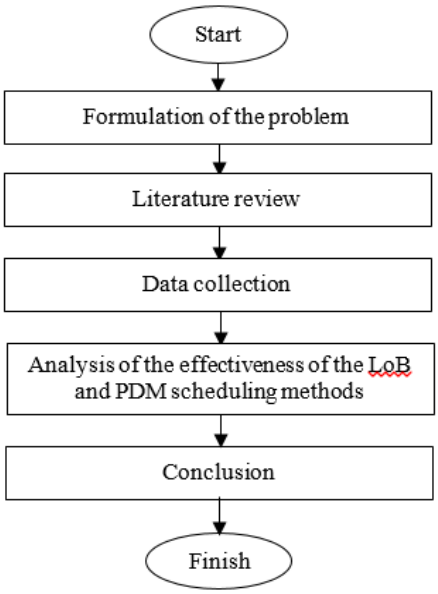

Figure 1. Operational model of the research

Data analysis of the LoB scheduling method uses Microsoft Excel 2019 software to recalculate the rescheduling time and create a linear graph of a linear group of work types. The stages of making a scheduling with the LoB method are identifying activities that are the same and repetitive, determining activity sequence and dependency logic, division of groups per work, calculating the number of effective working hours, calculating work time plan, calculating working hours per workgroup, determination of the number of work groups, determining the starting time of each work per unit and the last unit, determining buffer time based on experience logic, LoB schedule generation and drawing of scheduling diagram. Based on the project s-curve data obtained, a grouping of typical jobs is then made. Furthermore, from the grouping, the sequence of each activity is made (sequential). After that, the duration/schedule of each job is determined, then entered in the LoB table.

Data processing and analysis of the PDM scheduling method using Microsoft Project 2019 software to recalculate the project work time (rescheduling). The stages of making .scheduling with the PDM method are identifying activities in construction work, determining the sequence of activities and activity relationships, calculating the number of effective working hours, calculating the artistry time plan, calculating working hours per workgroup, determining the start time of each work per unit and the last unit, and drawing network diagram. Based on the project s-curve data, work sequencing is immediately carried out and then the schedule/duration of each activity is determined. Then the precende diagram method is developed.

Furthermore, the total duration is compared between LoB scheduling and PDM scheduling.

Result

The Covid Center Building Construction Project is carried out with a duration of 102 calendar days. It has a description of activities which are divided into eight work divisions, including preparatory work and construction, earthwork and lower structure, building superstructure work, wall pairing work, roofing and ACP work, mechanical, electrical, and plumbing work, HEPA filter work and medical gas network installation, and paving, garden, elevator, and final cleaning work.

In this research, the project schedule will be made using the line of balance method and precedence diagram method to get a comparison when applied to a multi-story building construction project. Project scheduling is based on project scheduling data made by the project owner. In conducting analysis and calculations, Microsoft Excel and Microsoft Project facilitate calculations and create the necessary graphs and diagrams. The project data used in preparing the new project scheduling consists of project curves and cost budget plans. These data are not directly used to make new project scheduling but are analyzed first so that they can be effectively applied to each method.

Project scheduling using line of balance

The WBS of the Covid Center Building Construction Project, Parepare, can be seen in Figure 2. The project WBS data makes a list of works with the same resource usage. It is done to make it easier to arrange project scheduling with the LoB method. For the duration of the project time, follow the project scheduling data. WBS development includes: (i) Construction preparation & OHS Work; (ii) Sub-structure building work; (iii) Upper-structure building work; (iv) Wall mansory work; (v) Roofing & ACP work; (vi) Mechanical Sanitary & Electrical work; (vii) Medical Gas Network Installation work; (viii) Road, paving, garden, lift and final cleaning work.

Work sequence logic is the relationship between one work and another. In preparing project scheduling, it is necessary to establish a relationship between work items. The preparation of work sequence logic is arranged in such a way that it can produce project scheduling with continuous use of resources. Line of balance will be applied to the overall scheduling, including preparatory work, earthwork, sub-structure and superstructure work, wall masonry work, roofing work, mechanical, electrical, and plumbing work, medical gas network installation work, and finishing work. An overview of the work sequence with reference to the WBS Structure is depicted in Figure 3.

Next, the schedule calculation is carried out using the LOB method. Scheduling the start date and finish date is influenced by the duration of the work to be calculated compared to the duration of the predecessor work. If the work (j) to be calculated has a faster duration than the predecessor work (i), then the determination of the date is calculated on the completion date, where the completion date of the work (j) is the sum of the completion date of the work (i) plus the duration of the last cycle of the work.

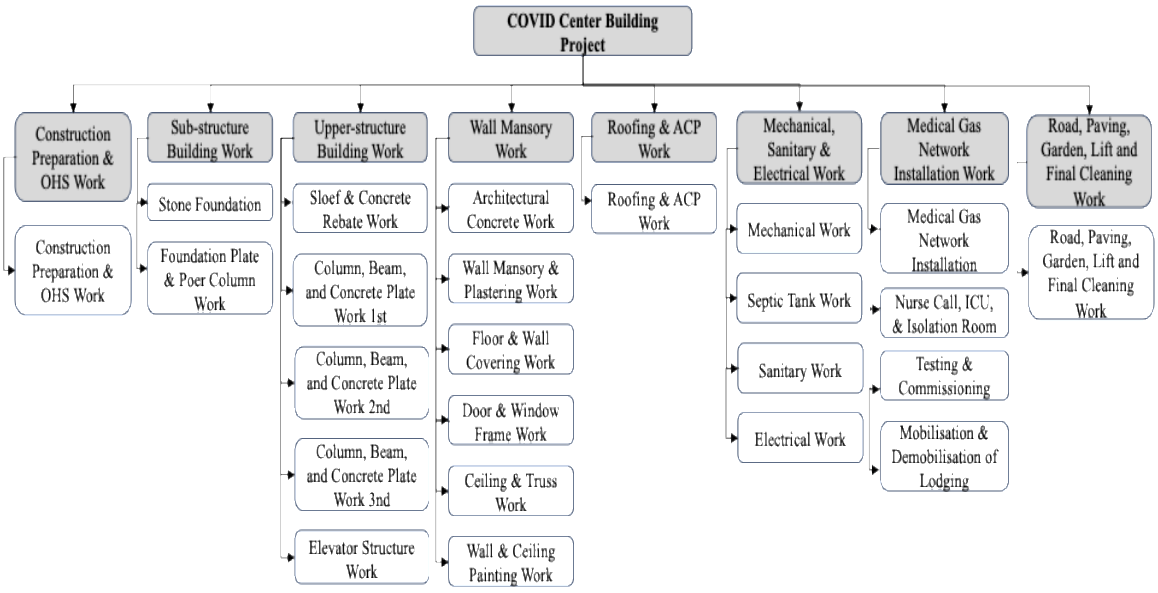

Figure 2. Projects work breakdown structure

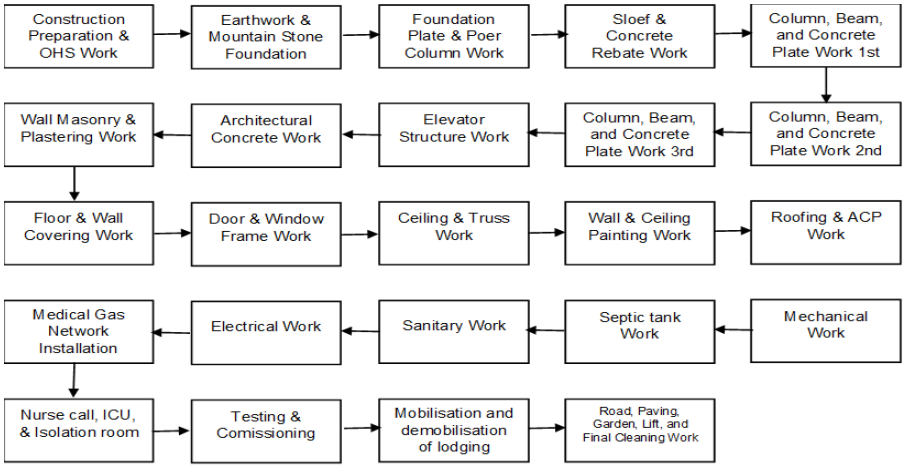

Figure 3. Work sequence logic

Based on Table 1, the overall duration of preparatory work, earthwork, sub-structure and superstructure work, wall masonry work, roofing work, mechanical, electrical, and plumbing work, medical gas network installation work, and finishing work resulting from scheduling using LoB is 101 days. The "preparation" work is planned to start on day 0 and finish on day 101.

"Soil and foundation" work is planned to start on day 5 and finish on day 40. The "plate foundation & poer column" work is planned to start on day 5 and finish on day 40. The work of "sloef and concrete rebate" is planned to start on day 19 and finish on day 40. Work on "concrete columns, beams, and slabs lt.1" work is scheduled to start on the 26th day and finish on the 40th day. The work of "columns, beams, and concrete slabs of 2nd floor" is planned to start on the 40th day and finish on the 54th day. The work of "columns, beams, and concrete slabs of 3rd floor" is planned to start on the 54th day and finish on the 68th day. The work of "elevator structure" is planned to start on the 26th day and also finish on the 68th day.

Table 1. Line of balance scheduling

Activity	Duration (day)	Calculation	Start	Calculation	Finish
Preparation & OHS work	101	0	0	0+101	101
Earthwork & mountain stone foundation	35	0+5	5	5+35	40
Foundation plate & poer column work	35	0+5	5	5+35	40
Sloef & concrete rebate work	21	5+14	19	19+21	40
Column, beam, and concrete plate work 1st	14	19+7	26	26+14	40
Column, beam, and concrete plate work 2nd	14	40	40	40+14	54
Column, beam, and concrete plate work 3rd	14	54	54	54+14	68
Elevator structure work	42	19+7	26	26+42	68
Architectural concrete work	28	54-7	47	47+28	75
Wall mansory & plastering work	35	47-7	40	40+35	75
Floor & wall covering work	28	82-28	54	75+7	82
Door & window frame work	35	54-7	47	47+35	82
Ceiling & truss work	28	47+7	54	54+28	82
Wall & ceiling painting work	19	82	82	82+19	101
Roofing & acp work	26	82-7	75	75+26	101
Mechanical work	35	75-15	60	60+35	95
Septic tank work	12	89	89	89+12	101
Sanitary work	14	60+7	67	67+14	81
Electrical work	28	67-7	60	60+28	88
Medical gas network installation	12	89	89	89+12	101
Nurse call, icu, & isolation room	12	89	89	89+12	101
Testing & commissioning	5	89+7	96	96+5	101
Mobilisation & demobilisation of lodging	101	0	0	0+101	101
Road, paving, garden, lift, and final cleaning work	19	89	89	89+12	101

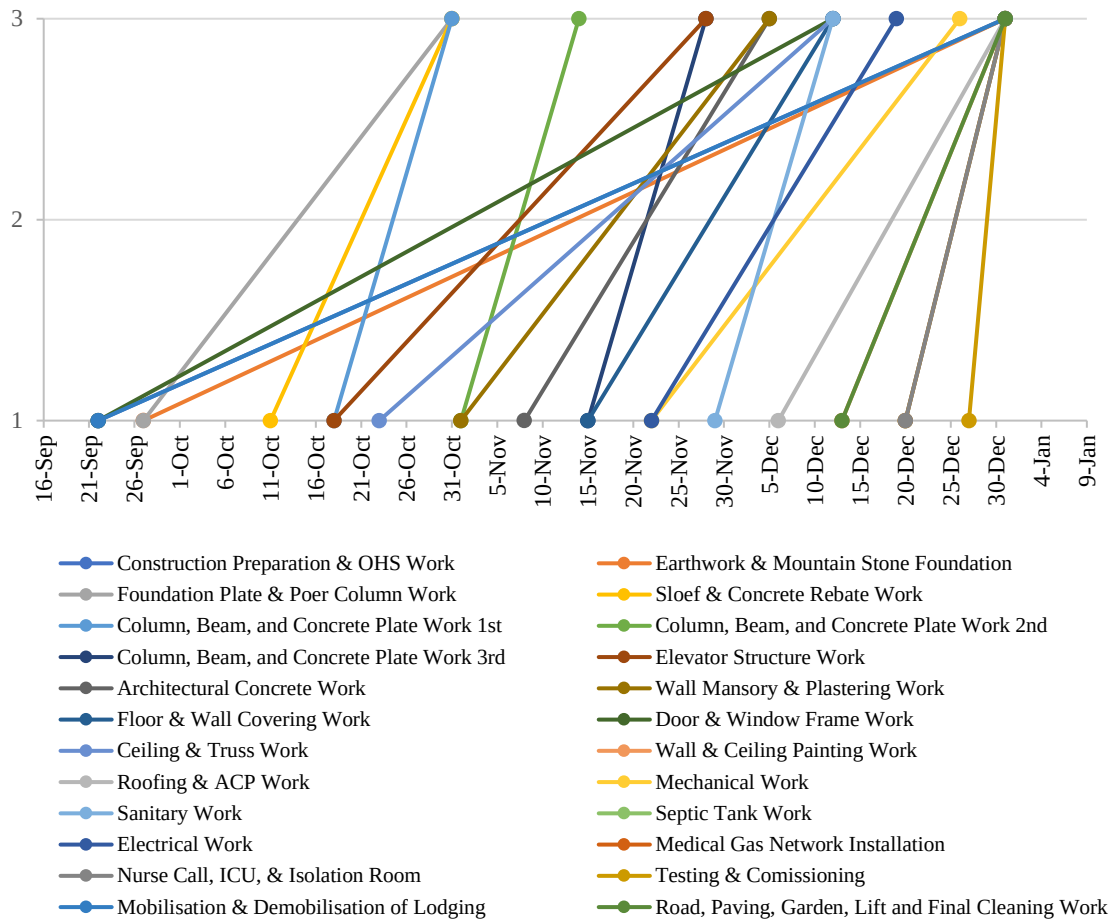

Figure 4. Line of balance of COVID center building project

The "architectural concrete" work is planned to start on the 47th day and finish on the 75th day. The "wall masonry and plastering" work is planned to start on the 40th day and finish on the 75th day. The "floor and wall covering" work is planned to start on day 54 and finish on day 82. The "door and window frames" work is planned to start on the 47th day and finish on the 82nd day. The "ceiling and truss" work is planned to start on day 54 and finish on day 82. The "wall and ceiling painting" work is planned to start on the 82nd day and finish on the 101st day. The "roofing and ACP" work is planned to start on day 75 and finish on day 101. The "mechanical" work is planned to start on 60th day and completed on the 95th day. The "septic tank" work is planned to start on the 89th day and finish on the 101st day. The "sanitary ware" work is planned to start on the 67th day and finish on the 81st day and "Electrical" work is planned to start on the 60th day and finish on the 88th day.

The "medical gas network installation" work is planned to start on the 89th day and finish on the 101st day. The "nurse call, icu room, and isolation room" work is planned to start on day 89 and finish on day 101. The "testing and commissioning" work is planned to start on day 96 and finish on day 101. The "lodging demobilization mobilization" work is planned to start on day 0 and finish on day 101. The work of "road, paving, garden, elevator, and final cleaning" is planned to start on day 89 and finish on day 101. The complete and comprehensive results of scheduling calculations for the Covid Center Building Construction Project, Parepare using the LoB method are shown in Figure 4 above.

Project scheduling using precedence diagram

PDM is a project scheduling in the form of a network diagram. Transferring project schedule to a bar chart to get a dependency relationship between works; perform forward calculations to get the Earliest Start (ES) and Earliest Finish (EF); Perform backward calculations to get the Latest Start (LS) and Latest Finish (LF); Compile ES, EF, LS, & LF data to get critical works; and create a precedence diagram. Before preparing project scheduling, it is necessary to know the sequence of project work to determine the relationship between work items. The project dependency logic is given in Table 2.

Table 2. Logic of work dependencies

Activity	Symbol	Depends on	Overlap		Duration (day)
			Type	LT	
Construction preparation & OHS Work	A	START	-	-	101
Foundation	B	A	STS	5	35
Foundation plate & poer column work	C	B	STS	0	35
Sloef & concrete rebate work	D	C	STS	14	21
Column, beam, and concrete plate work 1st	E	D	STS	7	14
Column, beam, and concrete plate work 2nd	F	E	FTS	0	14
Column, beam, and concrete plate work 3rd	G	E, F	FTS	0	14
Elevator structure work	H	E	STS	0	42
Architectural concrete work	1	G	STS	-7	28
Wall mansory & plastering work	J	I	STS	-7	35
Floor & wall covering work	K	J	FTF	7	28
Door & window frame work	L	J	STS	7	35
Ceiling & truss work	M	L	FTF	0	28
Wall & ceiling painting work	N	K, L, M	FTS	0	19
Roofing & acp work	O	N	FTF	0	26
Mechanical work	P	O	STS	-14	35
Septic tank work	Q	P	FTF	0	12
Sanitary work	R	Q	STS	7	14
Electrical work	S	R	STS	0	28
Medical gas network installation	T	S	FTS	0	12
Nurse call, icu, & isolation room	U	T	STS	0	12
Testing & commissioning	V	U, X	FTF	0	5
Mobilisation & demobilisation of lodging	W	A	STS	0	101
Road, paving, garden, lift and final cleaning work	X	K, L, M, R	FTS	0	19

Discussion

The Line of Balance (LoB) method can provide significant advantages when dealing with repetitive building construction projects, such as three-storey buildings. LoB allows efficient scheduling of repetitive works on each floor, taking into account the dependency and logic between works. This approach helps to optimally manage resources and minimise wasted time. In addition, the LoB provides good visibility into the progress of the works over time, allowing the project to stay on track. On the other hand, Precedence Diagram Method (PDM) offers flexibility in planning construction projects in detail.

PDM uses network diagrams to show dependencies between tasks and allows for a clear determination of the critical path. This gives project managers greater control over the timing and sequence of work. However, PDM may be more complex in situations where there are many repetitive tasks, such as in the construction of buildings with multiple identical floors. The critique of this research is to demonstrate that for building projects two scheduling techniques can be used, namely LoB and PDM. The advantages of LoB for repetitive work because of its advantages can be seen cross section of one group of work and other groups of work.

In this research, before the preparation of LoB and PDM schedules, the first step taken is to compile the WBS of the project. Based on this WBS, this is the reference for the activities that will be compiled in the LoB and PDM. In terms of timeliness and handling repetitive work, Line of Balance has the advantage of focusing on dependency and repetition of work. However, PDM provides greater control in understanding and managing complex dependencies throughout the project. The selection of LoB and PDM methods may depend on the complexity of the project, the degree of repetition of work, and the preferences of project management. Overall, both Line of Balance and Precedence Diagram Method have their own advantages and disadvantages. Based on the calculation results of Early Start (ES), Early Finish (EF), Late Start (LS), Late Finish (LF) in Table 3, activities are then obtained which are critical activities which are described in Table 3.

Conclusion

From the results of the preparation of project scheduling with the two methods, namely LoB and PDM, it can be concluded that: LoB and PDM methods can plan project scheduling on repetitive work while maintaining the continuity of labor use characterized by the absence of work breaks.

Table 3. Critical work calculation

Act	ES	EF	LS	LF	D	LF-LS	Status
A	0	101	2	103	101	103	
B	5	40	40	75	35	70	
C	5	40	40	75	35	70	
D	19	40	54	75	21	56	
E	26	40	61	75	14	49	
F	40	54	75	89	14	49	
G	54	68	89	103	14	49	
H	26	68	61	103	42	77	
1	47	75	75	103	28	56	
J	40	75	40	75	35	35	C
K	54	82	54	82	28	28	C
L	47	82	47	82	35	35	C
M	54	82	54	82	28	28	C
N	82	101	82	101	19	19	C
O	75	101	75	101	26	26	C
P	61	96	63	98	35	37	
Q	75	101	91	103	12	28	
R	68	82	70	84	14	16	
S	61	89	63	91	28	30	
T	61	73	91	103	12	42	
U	61	73	91	103	12	42	
V	96	101	98	103	5	7	
W	0	101	2	103	101	103	
X	82	101	84	103	19	21	

Note : C=critical

The advantages of LoB method project scheduling over the PDM method are: (i) The analysis of project scheduling calculations is relatively simple, (ii) The visual appearance of the scheduling diagram is easy to read and understand, (iii) The daily or weekly project progress rate can be know. The weaknesses of the LoB method project scheduling compared to the PDM method are: (i) The dependency relationship between activities, especially for activities that have more than one dependency relationship, is less clear, (ii) For more complex work with many work items, it is relatively tricky, (iii) The use of LoB and PDM methods at the same time in scheduling can provide good scheduling results, both in terms of labor continuity and dependency relationships between activities.

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