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Construction Project Scheduling Optimization with Critical Path Method (CPM) and Precedence Diagram Method (PDM) (Case Study: PT Samara Insan Sentosa)

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ABSTRACT

Delays in construction projects often occur due to suboptimal scheduling, which results in increased costs and decreased efficiency. PT Samara Insan Sentosa faces a similar problem, where the planned project duration does not match the realization in the field. This study aims to optimize project scheduling using the Critical Path Method (CPM) and Precedence Diagram Method (PDM). The research methods used include secondary data analysis, interviews, and scheduling calculations with both methods. The results of the study show that CPM and PDM can identify critical paths and optimize project completion duration. A comparison of the two methods shows that PDM is more flexible than CPM, with a shorter project completion duration. Implementation of the PDM method can reduce project completion time without sacrificing the quality of work. The conclusion of this study is that scheduling optimization using the right method can increase project efficiency and reduce the risk of delays. The impact of this study can help companies improve the effectiveness of project management.

Keywords: *Project scheduling, Critical Path Method (CPM), Precedence Diagram Method (PDM), critical path, optimization.*

Introduction

A project is an activity where the amount of time and resources are limited for the desired/determined end result [1]. Project completion must be carried out within a predetermined time limit with the use of limited resources [2]. Alternative scheduling methods are needed, because although project progress can be compared with the planned schedule, the information that can be conveyed is very limited [3].

Often there are many changes from the initial design when the project is implemented in the field [4]. Proper scheduling is undoubtedly needed for large projects in order to achieve optimal construction time and costs [5]. One of the most important factors in reducing project losses or even failure is effective scheduling [6].

Scheduling is a phase that translates plans into diagrams that are in accordance with the time scale[7]. The time sequence of project activities is known as project scheduling and serves as a useful guide while the project is being implemented [6]. Helping the team remember that the allocated tasks have a deadline is the main purpose of project scheduling [1]. To prevent delays in project completion, contractors must create a network method scheduling management that is in accordance with the characteristics of the project and is easy to monitor at any time. Thus, contractors can schedule each project activity item as efficiently and optimally as possible [8].

The implementation of work is often delayed due to minimal control and less than optimal scheduling [9]. Project delays are a very undesirable condition, because they will harm both parties in terms of cost and time [1]. Cost and time have a direct correlation with the delay in project completion. The longer the project is delayed, the more money and time it takes to complete it [6]. The timeliness of project completion is unknown because the type and field of the project can affect the length of time the project takes to complete[1].

The success or failure of a project is largely determined by its budget and schedule [3]. The project implementer will lose if the project implementation time is less than the target, because the delay in the completion date will increase the cost of project implementation [10]. Effective schedule planning can calculate time and costs in the best possible way. The Precedence Diagram Method (PDM) and the Critical Path Method (CPM) are two widely used scheduling approaches [5].

Network diagrams are used to describe the process of modeling project activities known as the Critical Path Method (CPM) [11]. In terms of organizing, scheduling, and managing organizational resources, CPM, commonly referred to as AOA (Activity On Arrow), is a fundamental project management approach [5]. The CPM method is known as the critical path concept, which plays an important role in project implementation because every activity on this path must be started and completed on time [8]. The Precedence Diagram Method is one of the network-based project scheduling methods that is included in the AON (Activity On Node) category [9]. The Precedence Diagram Method (PDM) is a form of refinement of the CPM method, which initially only relied on one type of relationship between activities, namely the finish-to-start relationship, so that an activity can be started after the previous activity is completed [6].

The way information is presented as a scheduling tool is one of the many differences between the PDM and CPM approaches [12]. The Prece-dence Diagram Method (PDM) includes four main types of time constraints in project activity scheduling, namely Early Start (ES) which indicates the earliest time an activity can be started, Early Finish (EF) which indicates the earliest time the activity can be completed, Late Start (LS) which indicates the latest time an activity can be started without causing project delays, and Late Finish (LF) which is the latest time an activity can be completed without affecting the overall project schedule, cpm contains Imaginary work items [12]. CPM and PDM have similarities in their completion steps, namely starting by analyzing the relationships between activities, compiling network diagrams, performing forward and backward calculations, calculating float, and determining the critical path [5].

[13] have researched the Implementation of the Critical Path Method in the Synthesis Residence Kemang Project. The Tower 2 Raft Foundation Work, Tower 2 Retaining Wall Work, and Basement Excavation Work were all completed on the critical path using the Critical Path Method (CPM). Based on the results of the CPM method calculations, the schedule shown was 484 days with a cost of IDR 62,110,831,400, - requiring 369 days with a cost of IDR 62,852,324,528, - In addition, [3] have researched discussing the rescheduling of the construction of new classrooms at MTsN Karangasem by applying the Precedence Diagram Method. The project duration is less than the anticipated time schedule and project implementation, according to the rescheduling findings obtained using the PDM Method resulting in a duration of 127 days, which means 8 days shorter than the projected project duration of 135 days.

PT Samara Insan Sentosa is a company engaged in the implementation of construction and development projects in BSD Tangerang. Although this company has made maximum efforts in running the project, it still faces obstacles related to project scheduling arrangements. So far, project schedule planning still relies on Microsoft Excel, with calculations and time allocation for each activity carried out manually. This condition results in the schedule being less efficient and requiring a relatively long time to complete.

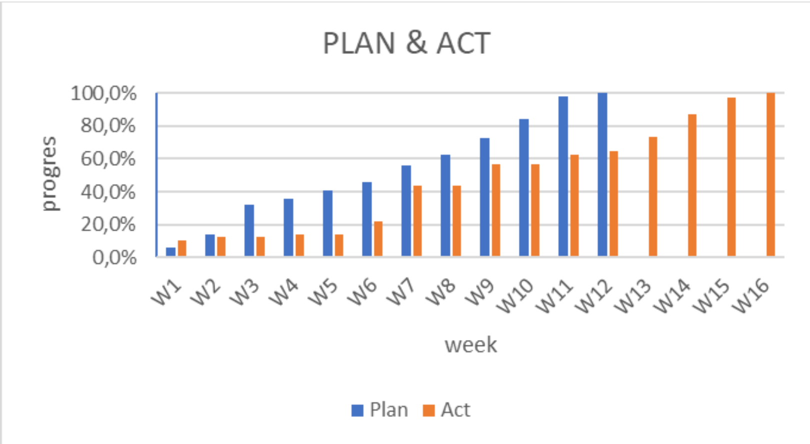

Figure 1. Plan & Actual Progress

The problem found in the construction project in this study was the inconsistency of the time duration planned by the project manager with the actual construction reality. From the graph above, it can be seen that the construction project planning was planned to be completed in 12 weeks, but in reality the construction was completed in 16 weeks. According to interviews conducted by the researcher with the project manager, there were several factors that caused the inconsistency in the project completion time. One of them was the late delivery of materials that had to be purchased for certain activities.

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Research Methods

This study aims to optimize the creation of a project schedule using the CPM and PDM methods, so that an optimal project schedule is obtained compared to the project schedule used previously. The stages of the research method include preliminary studies, literature studies, problem identification, problem formulation, company data collection, data processing using the CPM and PDM methods to obtain optimal scheduling results, discussions, and conclusions and suggestions. The CPM and PDM methods were chosen in this study because they have their own advantages compared to other optimization techniques, such as the S curve used by the company. The S curve method only shows cumulative progress and costs, without identifying which activities are critical and can cause delays if delayed. While the CPM and PDM methods can show the critical path, so that project managers know which activities should be prioritized.

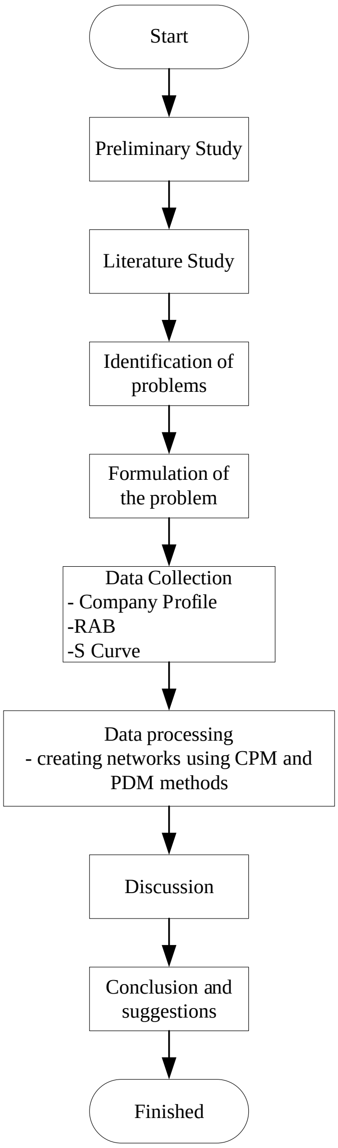

Figure 2. Research Flow Diagram

1. **Preliminary study**

   The steps in the research process begin with the implementation of a preliminary study. This initial stage includes the activities of searching for and collecting various relevant and supportive information on the main topic to be researched, namely project management. This information is obtained from various sources, both in the form of literature, scientific journals, articles, and other references that can provide an initial understanding and a strong theoretical basis before entering a more in-depth research stage.

2. Literature Study

After the preliminary study stage is completed, the next step is a literature study. This activity aims to explore, examine, and understand various theories, concepts, and previous research results that are closely related to the problems raised in this study. Through literature studies, researchers can obtain a strong and in-depth theoretical basis, which will later be used as a reference in formulating a framework of thought, designing research methodology, and analyzing findings in the field.

3. Identification of problem

In the next stage, the research enters the problem identification phase. This stage is an important process in order to identify and formulate various issues, challenges, or obstacles that arise during project implementation. Researchers systematically observe and examine real conditions in the field to find the main problems and supporting problems that have the potential to affect the success of the project. By conducting in-depth problem identification, research can be directed more focused and on target.

4. Formulation of the problem

After the problem identification process has been carried out thoroughly, the next step is to formulate the research problem. At this stage, the researcher begins to compile and determine a clear and focused problem statement, which is the result of an analysis of previously discovered issues. This problem formulation then becomes the basis for determining the direction and main objectives of the research. In other words, the formulation of the problem helps determine what is to be achieved through this research, as well as providing guidelines in compiling the theoretical framework and methodology to be used.

5. Data Collection

The next step in the research process is the data collection stage. In this phase, researchers begin to collect various information and data needed to support research analysis. The main focus at this stage is the collection of secondary data, namely data that is previously available and obtained from various reliable sources, such as project documents, official reports, archives, publications, and other institutional data that are directly related to the project that is the object of research. This secondary data serves as initial material to understand the project context more thoroughly and to support the interpretation of the problems that have been formulated previously.

6. Data Proccesing

After all the necessary data has been collected, the next step is to carry out the data processing process. At this stage, the data that has been obtained is analyzed and interpreted to obtain more meaningful information and support the achievement of research objectives. One of the techniques used in this data processing is the preparation of a project work network by utilizing the *Critical Path Method* (CPM) and *Precedence Diagram Method* (PDM). Both of these methods are used to map the sequence of activities in a project, identify critical paths, and determine the total duration of the project. By using these methods, researchers can analyze the relationships between activities, identify critical activities, and optimize the overall project implementation schedule.

7. Discussion

After all data processing processes are completed, the next stage in the research is discussion. At this stage, the researcher conducts an in-depth analysis of the results obtained from the previous data processing. This analysis aims to interpret the meaning of the processed data, relate it to relevant theories, and assess the extent to which the findings answer the problem formulation and support the achievement of research objectives. In this discussion, the researcher also describes the implications of the results obtained, compares them with findings from previous studies, and identifies factors that may influence the research results.

8. Conclusion and suggestion

The research process is closed with the final stage, namely the preparation of conclusions. At this stage, the researcher systematically summarizes the results obtained from the previous discussion process. The conclusion serves to provide a concise but comprehensive overview and summary of the main findings in the study. In addition, the conclusion also reaffirms whether the research objectives have been achieved and how the research results answer the formulation of the problems that have been set. Thus, the conclusion becomes an important part in presenting the core of the entire research process clearly and directed.

Framework of thingking

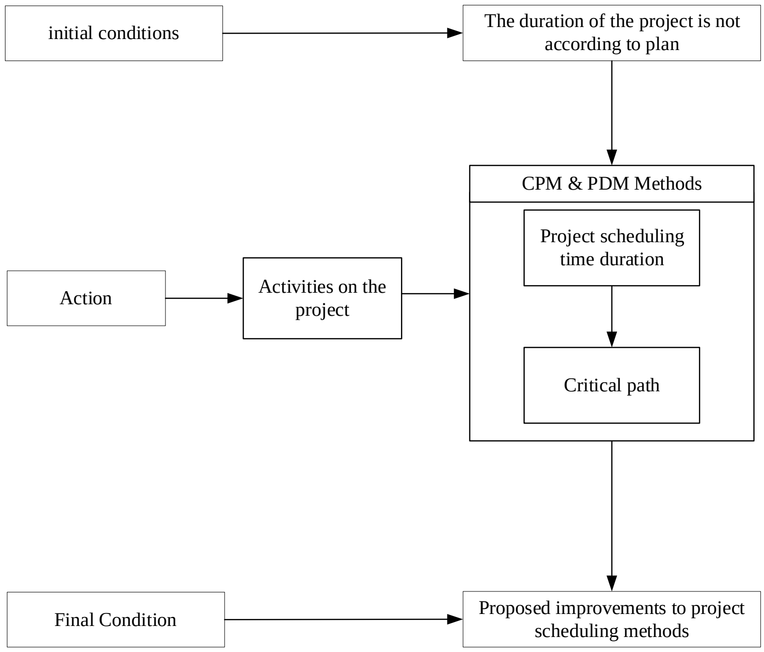

Figure 3. Framework of thingking

The framework of thought in this study begins with the identification of the initial conditions of the project scheduling prepared by the company, where there was a discrepancy between the initial plan and the realization of its implementation. In response to this problem, the researcher took steps to reschedule the project using the *Critical Path Method* (CPM) and *Precedence Diagram Method* (PDM). Through the application of these two methods, the results obtained were a more efficient project implementation duration and identification of critical paths that affect the overall project completion time. The final condition resulting from this study was a proposal for improvements to a more effective and structured project scheduling method.

Results

1. general project data

This study focuses on the preparation of construction project scheduling plans by comparing two methods commonly used in project management, namely the Critical Path Method (CPM) and the Precedence Diagram Method (PDM). This comparison is carried out to assess the effectiveness of each method in optimizing project implementation time, so that it can provide a more appropriate basis for decision making related to schedule planning and control. In addition, the S-curve method applied by the company will be analyzed to obtain a comparison in increasing time efficiency. The preparation of the project schedule is based on scheduling data that has been prepared by the project implementer. To facilitate the analysis and calculation process, Microsoft Project and POM-QM software are used. The scope of work on this project is as follows:

1. Preparation Work
2. Excavation, Sloof & Footing Work
3. Concrete Structure Work
4. Wall Work
5. Floor & Coating Work
6. Frame & Door Work
7. Ceiling Work
8. Painting Work
9. Sanitary Work
10. Clean & Dirty Water Installation Work

11. Electrical Installation Work
12. Roof Work
13. Other Work

2. Work Breakdown Structure

The grouping of project activities must be determined and arranged based on the structure that has been designed, namely through the Work Breakdown Structure (WBS). WBS plays a role in describing the entire project activity during the implementation process. In addition, WBS is also the basis for determining the duration of the work and functions as the main guide in preparing the project schedule. The following is the work breakdown structure found in the PT Samara Insan Sentosa project:

Table 1. Work Breakdown Structure

WBS	**TASK NAME**	**Daily**	**Weekly**
1	TYPE 30/60 HOUSE SAMARALAND		
1.1	**A. PREPARATION WORK**		**1**
1.1.1	Ulizet & Bouwplank	7	
1.2	**B. EXCAVATION WORK, SLOOF & FOUNDATION**		**4**
1.2.1	Foundation Soil Excavation	4	
1.2.2	River Stone Foundation	7	
1.2.3	Sand Fill t = 5 cm below the Foundation	1	
1.2.4	Backfill Foundation	3	
1.2.5	Compaction	2	
1.2.6	K225 Concrete Sloof + Formwork	11	
1.3	**C. CONCRETE STRUCTURE WORK**		**9**
1.3.1	K225 Concrete - Carport		
1.3.1.1	Land preparation and formwork installation	4	
1.3.1.2	Concrete casting	1	
1.3.1.3	Concrete care and curing	14	
1.3.2	K225 Concrete + Formwork		
1.3.2.1	Manufacture & installation of formwork for sloof, columns, beams	10	
1.3.2.2	Concrete casting	2	
1.3.2.3	Concrete care and curing	24	
1.3.2.4	Formwork dismantling and finishing	8	
1.4	**D. WALL WORK**		**10**
1.4.1	1:5 lightweight brick wall pair		
1.4.1.1	Lightweight brick laying work	20	
1.4.1.2	Checking and tidying up connections	3	
1.4.2	Plaster		
1.4.2.1	Preparation and cleaning of wall surfaces	2	
1.4.2.2	Wall plastering work	17	
1.4.2.3	Treatment (curing so the plaster doesn't crack)	5	
1.4.3	Plastering		
1.4.3.1	Surface preparation (check humidity and cleanliness)	2	
1.4.3.2	Plastering work	15	
1.4.3.3	Final result checking and tidying up	6	
1.5	**E. FLOORING WORK AND COATINGS**		**3**
1.5.1	FLOOR CERAMIC		
1.5.1.1	Type H1 (Main interior)	7	

1.5.1.2	Type H2 (Terrace)	3,5	
1.5.1.3	Type20X20 (Bathroom)	3	
1.5.1.4	HT 10x50 Ceramic Plinth (Bottom Wall Edge List)	2,5	
1.5.2	WALL CERAMIC		
1.5.2.1	Type 20X25 (Bathroom)	4	
1.6	**F. FRAME & DOOR WORK**		**3**
1.6.1	PJ1	6	
1.6.2	J1	4	
1.6.3	J2	4	
1.6.4	P1	3	
1.6.5	P2 (Glass Sliding Door)	2	
1.6.6	P3 (Bathroom)	2	
1.7	**G. CEILING WORK**		**2**
1.7.1	Gypsum Ceiling	14	
1.8	**H. PAINTING WORK**		**6**
1.8.1	INTERIOR & EXTERIOR WALL PAINT		
1.8.1.1	Wall	21	
1.8.1.2	Ceiling Paint	21	
1.9	**I. SANITARY WORKS**		**2**
1.9.1	KITCHEN		
1.9.1.1	Material preparation & pipeline checking	1	
1.9.1.2	Zinc 1 Hole	1	
1.9.1.3	Kitchen Faucet	1	
1.9.2	BATHROOM		
1.9.2.1	Material preparation & pipeline checking	1	
1.9.2.2	Sitting Closet	1	
1.9.2.3	Jet Washer	1	
1.9.2.4	Shower head	1	
1.9.2.5	Floor drain	1	
1.9.2.6	Function check & repair if there is a leak	1	
1.9.3	Back Garden / Carport		
1.9.3.1	Material preparation & pipeline checking	1	
1.9.3.2	Faucet	1	
1.10	**J. CLEAN WATER & DIRTY WATER INSTALLATION WORKS**		**3**
1.10.1	Fit. PVC pipe dia. 3/4" AW Horizontal	3	
1.10.2	Fit. PVC pipe dia. 3/4" AW Vertical	2	
1.10.3	Stop Tap	1	
1.10.4	Shock 3/4"AW	1	
1.10.5	Shock 1"AW	1	
1.10.6	Keni 3/4"AW	1	
1.10.7	T 3/4"AW	1	
1.10.8	T 3"D	1	
1.10.9	Rainwater Pipe & FD PVC 3" D Horizontal	1	
1.10.10	PVC Rainwater Pipe 2" D Vertical	1	
1.10.11	Used Water Pipe & FD PVC 4" D Horizontal	2	
1.10.12	Shock 3"D	1	

1.10.13	Elbow 4"D	1	
1.10.14	Vlok Shock 3X2"D	1	
1.10.15	Elbow 3"D	1	
1.11	**K. ELECTRICAL INSTALLATION WORK**		**3**
1.11.1	Downlight Point (4")	3	
1.11.2	Lamp Fitting Point	2	
1.11.3	Stop Contact Point	2	
1.11.4	Single switch	2	
1.11.5	Double switch	2	
1.11.6	Telephone / internet Connector	2	
1.11.7	Antenna Connector	2	
1.11.8	ExhaustFan	2	
1.11.9	MCB + BOX	4	
1.12	**L. ROOF WORK**		**2**
1.12.1	Sand Spandek Roof	3	
1.12.2	Upper Ridge/Outer Ridge	2	
1.12.3	Bitumen Roof	3	
1.12.4	Lisplank GRC	2	
1.12.5	Galvalum Frame (Light Steel)	4	
1.13	**M. OTHER WORKS**		**6**
1.13.1	Water Proofing Roof Gutters	7	
1.13.2	Biofil Septic Tank	12	
1.13.3	Control tub	6	
1.13.4	Infiltration wells	10	
1.13.5	Water Pump House	7	
Total		372	53

3. CPM Method Analysis (Critical Path Method) Method

The CPM method is a technique used in planning and controlling project duration by identifying activities that are on the critical path.

Relationship between activities

In the analysis using the CPM method, after all the data is collected and the activities are detailed, it is necessary to determine the dependency relationship between tasks. The goal is to systematically arrange the sequence of activities in the form of a logical structure.

Table 2. Relationship between activities CPM

ACTIVITY CODE	ACTIVITY DESCRIPTION	PREVIOUS ACTIVITIES	ACTIVITY DURATION (Week)
A	PREPARATORY WORK	-	1
B	EXCAVATION WORK, SLOOF & FOUNDATION	A	4
C	CONCRETE STRUCTURE WORK	B	9
D	WALL WORK	C	10
E	FLOORING WORKS AND COATINGS	D	3
F	FRAME & DOOR WORK	E	3
G	CEILING WORK	F	2
H	PAINTING JOB	D	6
I	SANITARY WORKS	H	2
J	CLEAN WATER & DIRTY WATER INSTALLATION '	I	3
K	ELECTRICAL INSTALLATION WORK	J	3
L	ROOF WORK	K	2
M	OTHER WORKS	L	6

Forward Calculation

The forward calculation method is done by calculating from the beginning of the project to the end, to find out the early completion time (EF) by adding the early start time (ES) to the duration of the activity. The results of the forward calculation can be seen in the table below:

Table 3. Forward Calculation CPM

ACTIVITY CODE	ACTIVITY DESCRIPTION	ACTIVITY DURATION (Week)	ES	EF
A	PREPARATORY WORK	1	0	1
B	EXCAVATION WORK, SLOOF & FOUNDATION	4	1	5
C	CONCRETE STRUCTURE WORK	9	5	14
D	WALL WORK	10	14	24
E	FLOORING WORKS AND COATINGS	3	24	27
F	FRAME & DOOR WORK	3	27	30
G	CEILING WORK	2	30	32
H	PAINTING JOB	6	24	30
I	SANITARY WORKS	2	30	32
J	CLEAN WATER & DIRTY WATER INSTALLATION WORKS	3	32	35
K	ELECTRICAL INSTALLATION WORK	3	35	38
L	ROOF WORK	2	38	40
M	OTHER WORKS	6	40	46

Backward Calculation

The backward calculation method is carried out from the end point of the project starting point, with the aim of determining the Late Start (LS), which is the last time an activity can be started. LS is calculated by subtracting the Last Finish (LF) from the duration of the activity in question. The results of the backward calculation can be seen in the table below.

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Table 4. Backward Calculation CPM

ACTIVITY CODE	ACTIVITY DESCRIPTION	ACTIVITY DURATION (Week)	LS	LF
A	PREPARATORY WORK	1	0	1
B	EXCAVATION WORK, SLOOF & FOUNDATION	4	1	5
C	CONCRETE STRUCTURE WORK	9	5	14
D	WALL WORK	10	14	24
E	FLOORING WORKS AND COATINGS	3	38	41
F	FRAME & DOOR WORK	3	41	44
G	CEILING WORK	2	44	46
H	PAINTING JOB	6	24	30
I	SANITARY WORKS	2	30	32
J	CLEAN WATER & DIRTY WATER INSTALLATION WORKS	3	32	35
K	ELECTRICAL INSTALLATION WORK	3	35	38
L	ROOF WORK	2	38	40
M	OTHER WORKS	6	40	46

Total Slack Calculation

Free Slack for an activity can be calculated by subtracting the duration of the activity (t1) from the difference between the earliest start time (ES2) of the next activity and the start time of the activity being analyzed (ES1). Meanwhile, through backward calculation, Total Slack (TS) can be calculated using the formula TS = LS - ES or LF - EF.

Table 5. Total Slack Calculation CPM

ACTIVITY CODE	ACTIVITY DESCRIPTION	ACTIVITY DURATION (Week)	ES	EF	LS	LF	SLACK	Critical Path
A	PREPARATORY WORK	1	0	1	0	1	0	yes
B	EXCAVATION WORK, SLOOF & FOUNDATION	4	1	5	1	5	0	yes
C	CONCRETE STRUCTURE WORK	9	5	14	5	14	0	yes
D	WALL WORK	10	14	24	14	24	0	yes
E	FLOORING WORKS AND COATINGS	3	24	27	38	41	14	no
F	FRAME & DOOR WORK	3	27	30	41	44	14	no
G	CEILING WORK	2	30	32	44	46	14	no
H	PAINTING JOB	6	24	30	24	30	0	yes
I	SANITARY WORKS	2	30	32	30	32	0	yes
J	CLEAN WATER & DIRTY WATER INSTALLATION WORKS	3	32	35	32	35	0	yes
K	ELECTRICAL INSTALLATION WORK	3	35	38	35	38	0	yes
L	ROOF WORK	2	38	40	38	40	0	yes
M	OTHER WORKS	6	40	46	40	46	0	yes

An activity is categorized as a critical activity if it has no slack, meaning Total Slack and Free Slack are zero. Meanwhile, the Critical Path is a path that connects the starting point (Start) to the ending point (Finish) and consists of a series of critical activities.

CPM network diagram using POM QM

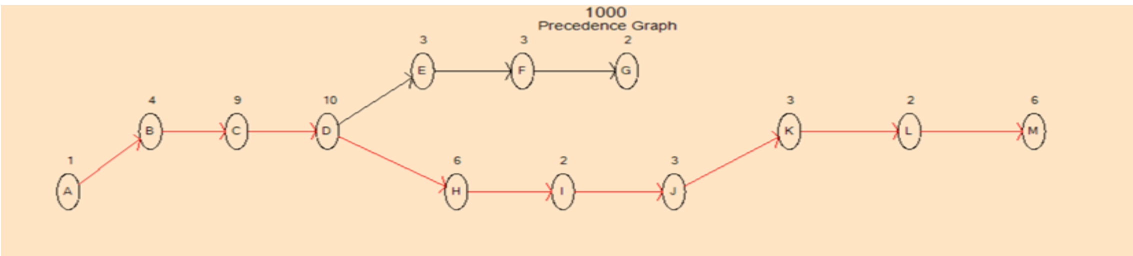

Figure 4. CPM Network Diagram

After forward and backward calculations, as well as float analysis, activities with a total float (TF) value of zero meet the criteria as part of the critical path. In the network diagram, these activities are marked in red as shown in Figure 4.1, so that the critical path for the CPM method is obtained, namely in activities A, B, C, D, H, I, J, K, L, M. The critical path is the path with the longest total time duration. The activity above has the longest duration, namely 46 weeks. Based on the calculation results using the CPM method, the total duration of the project is 46 weeks. However, when compared to the S-curve method used by the company, CPM shows lower efficiency, because the S-curve produces a faster completion time, namely 16 weeks.

4. PDM Method Analysis (Precedence diagram method)

Logical relationships between activities are determined by inputting dependency types such as FS (Finish to Start), SS (Start to Start), FF (Finish to Finish), and FS (Finish to Start) on each related activity. In this project, not all jobs have similar relationship patterns, some jobs start or finish simultaneously, while others can only be started after several days of the previous job completion. Therefore, the dependency between jobs in this project follows the predecessor concept, which is dependent on the previous activity. After all job dependencies are inputted, the process of entering project data into Microsoft Project 2010 is considered complete.

Relationship between activities

In the analysis using the PDM (Precedence Diagramming Method) method, after the data is collected and each activity is detailed, it is necessary to determine the dependency relationship between tasks. The purpose of this step is to systematically arrange the sequence of activities in the form of a network diagram, so that the project workflow can be visualized more flexibly.

Table 6. Relationship between activities

ACTIVITY CODE	ACTIVITY DESCRIPTION	PREVIOUS ACTIVITIES	ACTIVITY DURATION (Week)
A	PREPARATORY WORK	-	1
B	EXCAVATION WORK, SLOOF & FOUNDATION	-	4
C	CONCRETE STRUCTURE WORK	-	9
D	WALL WORK	3SS+14 days	10
E	FLOORING WORKS AND COATINGS	4FS-28 days	3
F	FRAME & DOOR WORK	5FS-7 days	3
G	CEILING WORK	6FS-42 days	2
H	PAINTING JOB	4FS-6 wks	6
I	SANITARY WORKS	8FS-2 wks	2
J	CLEAN WATER & DIRTY WATER INSTALLATION '	9FS-9 wks	3
K	ELECTRICAL INSTALLATION WORK	10	3
L	ROOF WORK	11FS-2 wks	2
M	OTHER WORKS	12FS-3 wks;7	6

Calculation of the PDM method work diagram

The PDM method in scheduling shows the sequence of activities and the critical path, which helps in facilitating the monitoring of project implementation. In this scheduling, the AON (Activity on Node) approach is applied to calculate the activity implementation time through two stages, namely the forward pass (including early start and early finish) and the backward pass (including late start and late finish). The results of these calculations produce free float and total float values, which are used to determine whether an activity is on the critical path or not. In this case study, the critical path was obtained with the help of Microsoft Project 2021 software and the results can be seen in the following table.

Table 7. Calculation of the PDM method

Task name	Early Start	Early Finish	Late Start	Late Finish	Total Slack	Critical
PREPARATORY WORK	0	1	13	14	13	no
EXCAVATION WORK, SLOOF & FOUNDATION	0	4	10	14	10	no
CONCRETE STRUCTURE WORK	0	9	0	9	0	yes
WALL WORK	2	12	2	12	0	yes
FLOORING WORKS AND COATINGS	8	11	8	11	0	yes
FRAME & DOOR WORK	10	13	10	13	0	yes
CEILING WORK	7	9	7	9	0	yes
PAINTING JOB	6	12	8	14	2	no
SANITARY WORKS	10	12	12	14	2	no
CLEAN WATER & DIRTY WATER INSTALLATION '	3	6	5	8	2	no
ELECTRICAL INSTALLATION WORK	6	9	8	11	2	no
ROOF WORK	9	11	9	11	0	yes
OTHER WORKS	8	14	8	14	0	yes

PDM network diagram using Microsoft Project

The following is a PDM network generated using Microsoft Project Software:

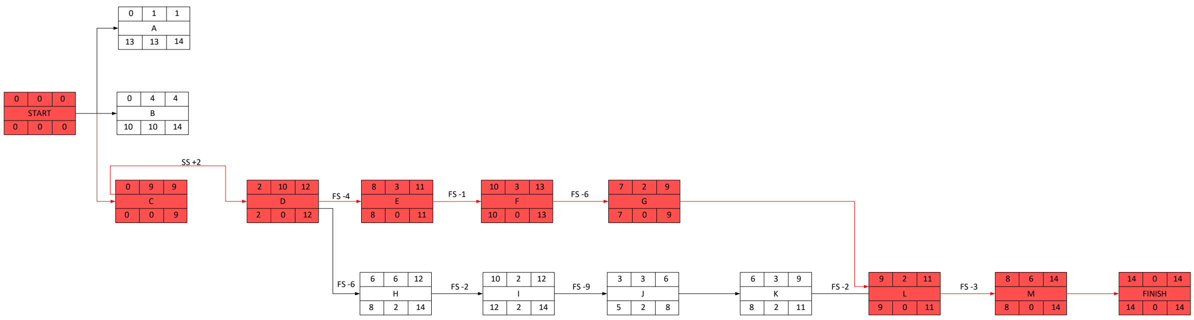

Figure 5. PDM Network Diagram

Discussion

Looking at the CPM and PDM calculations above, it is known that the critical path calculation in the CPM method is 46 weeks by adding up the critical activities, namely A, B, C, D, H, I, J, K, L, M. By using the PDM method, the critical path calculation shows a duration of 14 weeks, with critical activities including C, D, E, F, G, L, and M. Meanwhile, the analysis using the S Curve planned by the company produces a duration of 12 weeks.

However, based on field data, the project was completed in 16 weeks. This shows that project planning using the S Curve was delayed, because the realization of project completion was recorded in the 16th week. According to the results of interviews with the project manager, there were several factors that caused the discrepancy in the project completion time. One of them is the delay in materials that must be purchased for certain activities due to the delay in cash flow from house sales which caused materials not to be purchased for certain activities. However, the company does not know which activities should be a priority. This problem can be overcome by knowing the critical path so that the company can prioritize activities on the critical path.

The S curve method only shows cumulative progress and costs, without identifying which activities are critical and can cause delays if delayed. While the CPM and PDM methods can show the critical path, so that project managers know which activities should be prioritized.

Based on the research results, the CPM method produces fewer critical activities compared to the PDM method. However, considering that the housing construction project analyzed has a high level of complexity of relationships between activities, the PDM method is considered more appropriate to use. This is because PDM is able to model various types of activity dependencies more flexibly, such as start-to-start, finish-to-finish relationships, and the use of lead and lag time, which cannot be optimally accommodated by the CPM method.

Thus, although the number of critical activities generated by PDM is greater, it actually provides a more realistic picture of field conditions. This information is very useful for project management in determining material procurement priorities, resource allocation, and activity monitoring more effectively. Therefore, the use of the PDM method is more recommended in projects with a high level of complexity in order to minimize the risk of delays and increase accuracy in project planning and control.

Comparison of Methods

Based on the results of scheduling calculations, the PDM method is considered the most optimal because it produces a shorter completion time and can allow overlapping activities. With network rules that allow overlapping activities, the PDM method is able to accelerate the project duration compared to the CPM method and the S-Curve method, the following is a comparison of the three methods:

Table 8. Comparison of Methods

Characteristics	CPM	PDM	S Curve
Critical Path	A, B, C, D, H, I, J, K, L, M	C, D, E, F, G, L, M	-
Project Duration (weeks)	46	14	16
Dependency Logic	Finish to start	Finish to start, start to finish, start to start, finish to finish	-

Conclusion

Based on the analysis of construction project scheduling data carried out by PT Samara Insan Sentosa, it can be concluded that the project includes various types of main activities, including Preparation Work, Excavation Work, Sloof and Footing Foundation, Concrete Structure Work, Wall Work, Floor and Coating Work, Frame and Door Work, Ceiling Work, Painting Work, Sanitary Work, Clean and Waste Water Installation Work, Electrical Installation Work, and Roof Work. Through the application of the Critical Path Method (CPM), the critical path in this project was identified in activities with codes A, B, C, D, H, I, J, K, L, and M, with an estimated total project duration of 46 weeks. Meanwhile, the Precedence Diagram Method (PDM) method shows the critical path in activities coded C, D, E, F, G, L, and M, with a shorter completion duration, namely 14 weeks. The main problem faced in this project is the delay in completion of work caused by the instability of cash flow from house sales, which has an impact on the delay in material procurement. In addition, the company has not implemented a planning method that is able to identify priority activities accurately, because so far it has only used the S curve which does not show the critical path. By implementing the CPM and PDM methods, the company can more easily identify critical activities that need to be prioritized, especially in terms of material procurement, so that project planning can be carried out more efficiently and the project can be completed according to the set time target.

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