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Design and Build Project Scheduling Applications Using the Critical Path Method

Rancang Bangun Aplikasi Penjadwalan Proyek Menggunakan Metode Jalur Kritis

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A B S T R A C T

Effective project planning and scheduling is a crucial factor in ensuring the successful implementation of projects, especially in the construction sector. CV Kayfa Permata, a construction company, often faces challenges in managing project time and resources optimally. To overcome these challenges, this study aims to design and build a desktop/web-based project scheduling application that implements the Critical Path Method (CPM) method. The uniqueness of this application lies in its ability to automatically calculate critical paths, total project duration, as well as visualize work network diagrams, which are directly tailored to the operational needs of the local company. Different from a theoretical or simulation approach, this research produces an applicative solution that can be implemented directly in a real work environment. The application development methodology uses a waterfall approach, with stages of needs analysis, system design, implementation, and testing. The test results show that the app is able to improve the efficiency of project scheduling and simplify the decision-making process. With this application, it is hoped that the project scheduling process at CV Kayfa Permata will be more systematic, efficient, and measurable.

Keyword: Project Scheduling, Critical Path Method, Critical Path

A B S T R A K

Perencanaan dan penjadwalan proyek yang efektif merupakan faktor krusial dalam memastikan keberhasilan pelaksanaan proyek, khususnya di sektor konstruksi. CV Kayfa Permata, sebuah perusahaan konstruksi, sering menghadapi tantangan dalam mengelola waktu dan sumber daya proyek secara optimal. Untuk mengatasi tantangan tersebut, penelitian ini bertujuan untuk merancang dan membangun aplikasi penjadwalan proyek berbasis desktop/web yang menerapkan metode Critical Path Method (CPM). Keunikan aplikasi ini terletak pada kemampuannya untuk secara otomatis menghitung jalur kritis, total durasi proyek, serta memvisualisasikan diagram jaringan kerja yang disesuaikan langsung dengan kebutuhan operasional perusahaan lokal. Berbeda dengan pendekatan teoretis atau simulasi, penelitian ini menghasilkan solusi aplikatif yang dapat diimplementasikan langsung dalam lingkungan kerja nyata. Metodologi pengembangan aplikasi menggunakan pendekatan waterfall, dengan tahapan analisis kebutuhan, perancangan sistem, implementasi, dan pengujian. Hasil pengujian menunjukkan bahwa aplikasi ini mampu meningkatkan efisiensi penjadwalan proyek dan mempermudah proses pengambilan keputusan. Dengan adanya aplikasi ini, diharapkan proses penjadwalan proyek di CV Kayfa Permata menjadi lebih sistematis, efisien, dan terukur.

Kata Kunci: Penjadwalan Proyek, Metode Jalur Kritis, Jalur Kritis

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1. INTRODUCTION

The development of the construction industry in Indonesia is accelerating along with the increasing need for infrastructure, commercial buildings, and housing. In carrying out these construction projects, companies are required to have an effective and efficient project management system, especially in terms of planning the time for the implementation of activities. Inaccuracies in project scheduling can have major impacts, such as delays in completion, cost overruns, and conflicts in resource management [1].

CV Kayfa Permata is one of the companies engaged in construction services and project procurement. In the implementation of its projects, this company still uses manual methods in compiling and monitoring project schedules, such as through spreadsheets or physical records. This leads to low effectiveness in schedule supervision as well as a lack of accuracy in estimating project completion times [2]. Therefore, an information system is needed that can help organize project scheduling in a more structured, measurable, and accurate manner.

Critical Path Method (CPM) is one of the widely used project scheduling methods in the world of project management. This method serves to calculate the total duration of a project and identify critical paths—that is, the sequence of activities that determine the project's completion time. By knowing the critical paths, project managers can focus supervision on activities that do not have a tolerance for delays, so that projects can be completed on time [3] [4].

Through this research, the author designed and built a project scheduling application that implements the CPM method, and is expected to help CV Kayfa Permata in planning, monitoring, and evaluating projects more efficiently. Several methods can be used to analyze the optimal turnaround time of a project and the logic of dependencies between jobs to achieve optimal turnaround times and identify jobs that require special observations [5].

In the world of the construction and service industry, project scheduling is one of the key factors that determine the success of a project. CV Kayfa Permata as a company engaged in construction often faces challenges in managing project implementation time. Scheduling processes that are still done manually often lead to less than optimal time planning, resulting in a higher risk of project delays. This has an impact on client satisfaction and the company's operational efficiency. As the need for efficiency and effectiveness in project management grows, the use of information technology is becoming a very relevant solution [6].

This research has a major contribution in developing a project scheduling system based on the Critical Path Method (CPM) method that is directly integrated with the specific needs of medium-scale construction companies such as CV Kayfa Permata. Unlike common commercially available scheduling applications, the system is built with the company's actual business processes in mind, as well as presenting automated visualization of the work network and critical path calculations. Thus, this research provides practical and applicative solutions that can be directly implemented by construction industry players to improve efficiency and accuracy in project planning.

2. METHODOLOGY

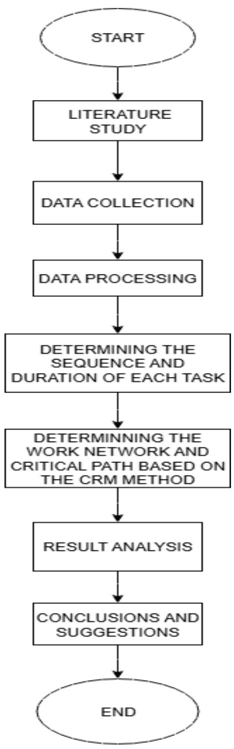

Figure 1. Research Flow

The scope of this research is concentrated in the field of Operational Management science. This study uses a type of descriptive quantitative data. This research was carried out on the paving block construction project. The data collection techniques used in this study are the direct observation method, the in-depth interview method, and the documentation study method [7].

The CPM method is a method of planning and controlling the progress of a job based on a work network [8]. The network analysis of the CPM method aims to determine the critical path that starts from the beginning of the project to the completion so this method is also known as the critical trajectory method. To determine the work network in CPM, there are two calculation methods used, namely [9] [10]:

1. Forward Pass
   a. Except for the initial work, a work can be started when the previous work has been completed.
   b. Earliest completion time of a job = 0
   c. The earliest completion time of a job is equal to the earliest start time and is added to the period of the work in question.

$$[\ EF = ES + D\ ] = \text{Earliest Start} + \text{Durasi} \quad (1)$$

   d. If a job has two or more previous jobs, then ES is the largest EF of that job.

2. Backward Pass
   a. The countdown starts from the last day of project completion of a work network.
   b. The last start time of a job is equal to the earliest start time and minus the duration of the activity in question.

$$[\ LS = LF - D\ ] = \text{Latest Finish} - \text{Durasi} \quad (2)$$

   c. If a job is divided into two or more jobs, then the LF of the job is equal to the next LS of the smallest job.

3. Float/Slack
   Float/slack is the delay time that an activity has without causing an overall project delay. Activities with a slack value = 0 are called critical activities and are on a critical path.

$$TF = LS - ES \text{ or } LF - EF \quad (3)$$

a. Critical Trajectory
   There are some project activities that have a delay tolerance limit, but there are also those that do not, so if there is a delay in these activities, it will affect the project completion time. Activities that do not have a delay tolerance limit are called activities. Critical trajectories are usually depicted with arrows that are thicker than regular trajectories [11].

b. Crashing Project
   The accelerated time (crash) of a project and accelerated costs (crash) have a negative relationship. This means that if the time is accelerated (shortened), the incremental cost will increase [12].

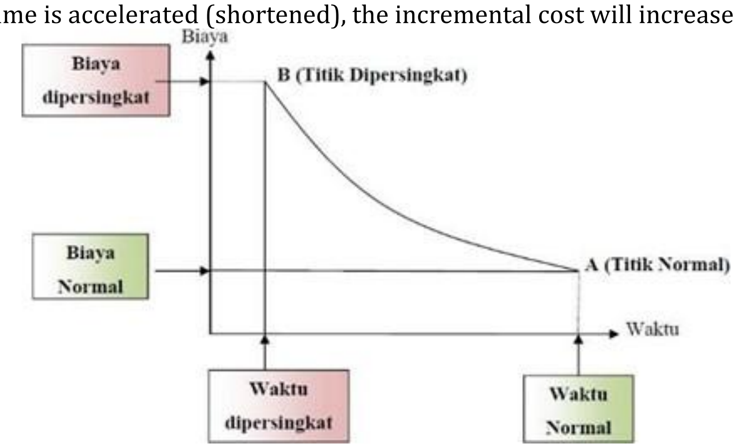

Figure 2. The Relationship Between Time and Cost

The increase in costs due to acceleration (cost slope) can be determined through the calculation of the cost of work against acceleration with the equation:

$$B' = \frac{D}{D'} x B \quad \text{..} (4)$$

Then after the accelerated cost is known, it can then determine the increase in costs due to the acceleration (cost slope) with the equation:

$$\text{cost slope} = \frac{B' - B}{D - D'} \quad \text{..} (5)$$

Where:
D = normal time
D' = time of fastening
B = normal cost
B' = accelerated cost

3. RESULTS AND DISCUSSION

3.1 Project Scheduling Data

Project Scheduling Data In the implementation of projects, scheduling is very important so that the planned work reaches the target with optimal results [13] . Based on the results of the interview, it is known that to see the progress of the project is to use daily reports and Bar Charts. The duration of the completion of the gate construction project is 21 weeks

Table 1. Project Progress Daily Report

JOB ITEMS	DURATION (weeks)
Prep Work	4
Pack. Soil and Foundation	3
Pack. Concrete Structure	9
Pack. Walls and Plastering	7
Pack. Floor	9
Pack. Ceiling	2
Pack. Frames and Window	8
Pack. Sanitation and Electricity	6
Pack. Painting	5
Pack. Miscellaneous	3
Pek. Finishing	2
Total	54

Source: CV. Kayfa Gems

3.2 Relationships between Jobs

The relationship between the works in the Taman Hutan Kota gate construction project is as follows:

Table 2. Relationships Between Jobs

CODE	JOB ITEMS	PREDECESSOR	DURATION (weeks)
A	Prep Work	-	4
B	Pack. Soil and Foundation	A	3
C	Pack. Concrete Structure	A	9
D	Pack. Walls and Plastering	B, C	7
And	Pack. Floor	C	9
F	Pack. Ceiling	I	2
G	Pack. Frames and Window	D, E	8
H	Pack. Sanitation and Electricity	G	6
I	Pack. Painting	H	5
J	Pack. Miscellaneous	I	3
K	Pek. Finishing	F, J	2
	Total		**54**

Source: research results (processed, 2023)

After knowing the relationship between the relationship and the duration of each job, the depiction of the work network can be done. This work network aims to detail which activities must be done first and which activities can be done next.

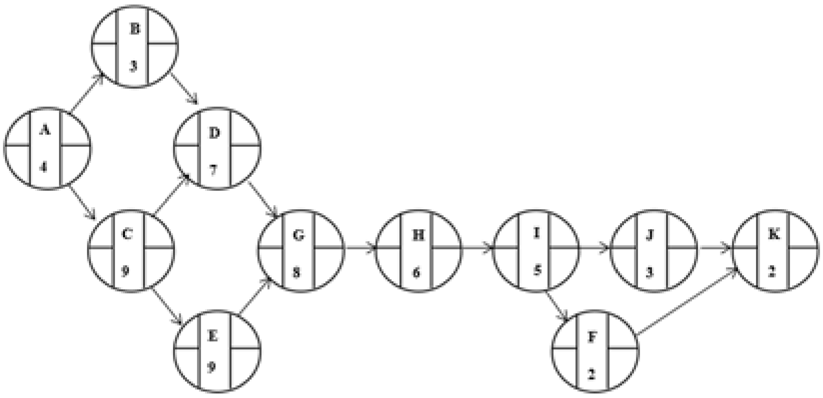

Figure 3. Paving block Construction Project Work Network

3.3 Determining the Critical Path

The next step after the compilation of the working network is to find the critical trajectory by performing a forward calculation to find the ES and EF values, followed by a countdown to find the LS and LF values, and then calculating the slack/float value to determine the critical path [14].

Table 3. CPM Calculation of Paving Block Construction Project

NO	CODE	Durai (mingu)	Account Maju		Account mundur		Float	Information
			IS	EF	LS	LF	TF	
1	A	4	0	4	0	4	0	Critical
2	B	3	4	7	12	15	8	Uncritical
3	C	9	4	13	4	13	0	Critical
4	D	7	13	20	15	22	2	Uncritical
5	And	9	13	22	13	22	0	Critical
6	F	2	41	43	42	44	1	Uncritical
7	G	8	22	30	22	30	0	Critical
8	H	6	30	36	30	36	0	Critical
9	I	5	36	41	36	41	0	Critical
10	J	3	41	44	41	44	0	Critical
11	K	2	44	46	44	46	0	Critical

Source: research results (processed, 2023)

Based on the calculation results, it is known that:
1. The critical trajectory of the Langsa City Forest Park gate construction project is in the work A – C – E – G – H – I – J – K because the total float = 0.
2. The duration of the project completion time is 79 days and can be accelerated from 10 weeks to 11 weeks.

In the form of a working network, the critical trajectory is marked with a thick arrow symbol which can be seen in the image below.

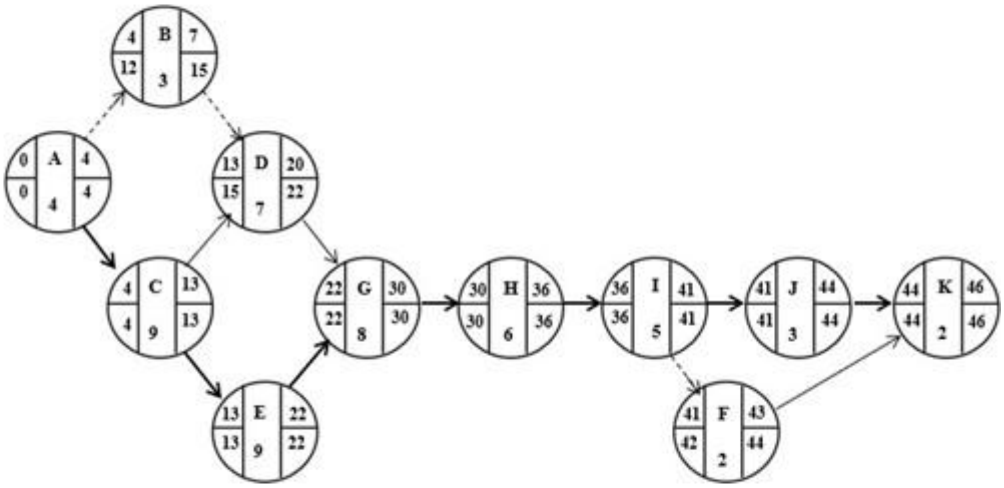

Figure 4. Critical Trajectory Network Diagram

3.4 Crashing Project

The increase in costs due to acceleration (cost slope) can be determined through the calculation of the cost of work against acceleration with equation 4 assuming the acceleration of time to 11 weeks by subtracting from the normal time of each job by 1 week [15].

Table 4. Calculation Results on Accelerated Costs

Code	Normal Time	Accelerated Time	Normal Fee (Rp)	Accelerated Cost (Rp)
A	4	3	12.562.000,00	10.749.333,30
B	3	2	186.432.207,00	16.432.207,00
C	9	8	91.729.097,70	55.728.645,00
D	7	6	28.088.260,82	116.291.853,00
And	9	8	10.962.285,70	21.729.097,70
F	2	1	19.407.300,00	36.176.521,60
G	8	7	91.470.479,60	70.962.285,70
H	6	5	49.170.000,00	9.407.300,00
I	5	4	4.620.000,00	11.470.479,60
J	3	2	8.780.000,00	19.170.000,00
K	2	1	2.310.000,00	4.620.000,00
		Total	**503.452.630,82**	**372.737.722,9**

Source: research results (processed, 2023)

Table 5. Cost Comparison Between Normal Time and Accelerated Time

DESCRIPTION	NORMAL	ACCELERATION	DIFFERENCE
Time	21 weeks	11 weeks	10 weeks
Cost	503.452.630,82	372.737.722,9	135.688.578,90

So the cost slope is obtained due to the acceleration *(cost slope)* as:

$$cost\ slope = \frac{B' - B}{- D'}$$

$$= \frac{\text{IDR } 503{,}452{,}630.82 - \text{IDR } 372{,}737{,}722.9}{21 \text{ weeks} - 11 \text{ weeks}}$$

= IDR 130,714,907.92

The relationship between cost, normal time, and accelerated time can be seen in the figure below:

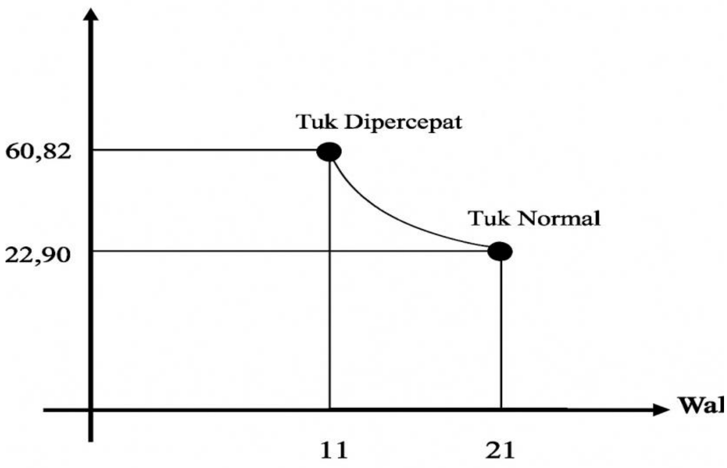

Figure 5. Graph of the Relationship Between Normal Time and Accelerated Time

3.5 System Implementation

This section presents the implementation of the main interfaces of the project scheduling application developed for CV Kayfa Permata. The figures illustrate functional modules that support the scheduling workflow, user management, and resource management. The following table summarizes each interface along with its main function, followed by brief descriptions of each view and a summary of the system testing results.

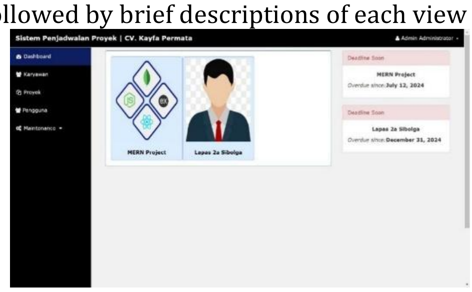

Figure 6. Dashboard

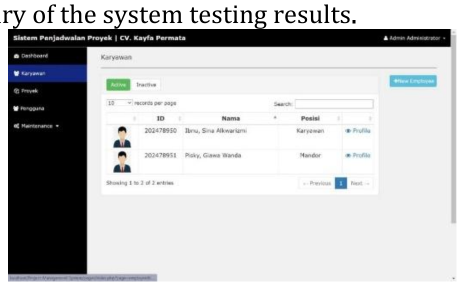

Figure 7. Employee data page

Figure 8. Completed project page

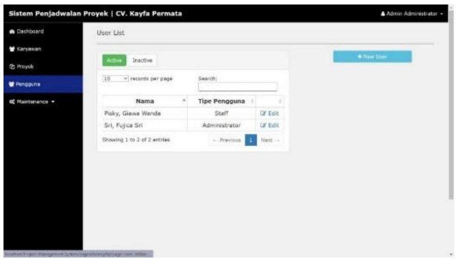

Figure 9. User List Page

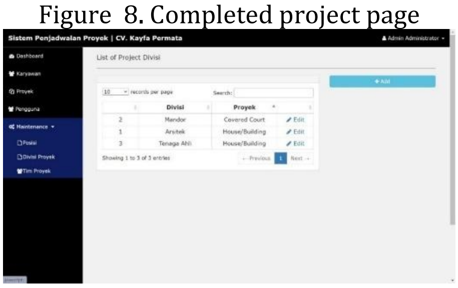

Figure 6. Next Project Page

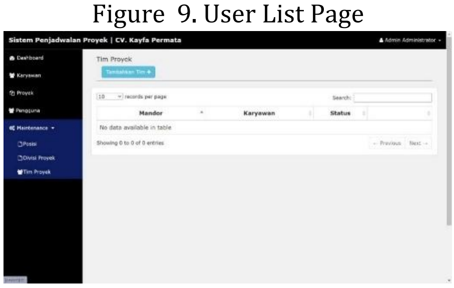

Figure 7. The project workers' page

Figures 6–11 display the main interfaces of the developed scheduling application: Figure 6 (Dashboard) presents a performance overview, project indicators, and quick visualizations for monitoring and decision-making; Figure 7 (Employee Data Page) shows detailed employee profiles (ID, name, position) that can be reviewed individually; Figure 8 (Completed Project Page) lists projects along with their status (completed/ongoing/failed), location, and deadline; Figure 9 (User List Page) displays a table of usernames and user types/roles for access management; Figure 10 (Next Project Page) presents division assignments and upcoming projects, facilitating workload planning; and Figure 11 (Project Workers' Page) shows the composition of team members for each project, allowing employees to identify their colleagues for specific tasks. Testing with users at CV Kayfa Permata demonstrated that these interfaces significantly speed up the calculation of critical paths and project duration estimates compared to manual methods, are considered easy to use, and provide informative work network visualizations. Usability evaluation using the System Usability Scale (SUS) produced an average score of 82.5 (Excellent category), indicating high usability and the potential to improve work efficiency.

3.6 Discussion

Based on the results of the implementation and testing of project scheduling applications using the Critical Path Method (CPM) method, the system is proven to be able to produce calculations of critical paths, total project duration, and work network visualizations automatically and accurately. These findings support the assertion that network-based methods such as CPM are highly effective in determining critical trajectories and aiding in timely project decision-making.

In addition, the ease of use and speed of the process generated by the application are in line with the research of Niyigena et al. [6], which show that the application of computerized information systems is able to improve the efficiency of operational management, including in the construction sector. The app makes it easier for project managers to identify critical activities, so that attention can be focused on the parts of the project that are most at risk of delays.

In contrast to previous research that only used CPM in the form of simulations or manual calculations [1], [3], this study presents a real contribution in the form of desktop/web-based applications that are ready to be used and have been tested in the context of the industrial world, namely in construction projects at CV Kayfa Permata. Thus, this study strengthens the literature on the application of the CPM method, while adding a practical dimension in the form of applicable technology products.

Evaluation using the System Usability Scale (SUS) which resulted in a score of 82.5 also showed that the system built was not only technically effective, but also had a high level of acceptance and user satisfaction. This reinforces the statement of [4] that the success of information systems is determined not only by their functionality, but also by their ease of use and user experience in interacting with the system. By comparing these results with relevant literature references, it can be concluded that the approach taken in this study is consistent with the direction of the development of modern information systems, namely user-centered and problem-oriented, and is able to answer specific challenges in the field

4. CONCLUSION

This research successfully designed and built a project scheduling application based on the Critical Path Method (CPM) method aimed at supporting the project planning and supervision process at CV Kayfa Permata. The developed application is capable of automatically calculating critical paths, determining the total duration of the project, and presenting a visualization of the network that makes it easier for users to understand the sequence and dependencies between activities.

The test results showed that the system provided accurate calculation results and improved efficiency compared to the manual methods previously used by the company. User evaluations also indicate a high level of satisfaction with the ease of use and functionality of the system, with a System Usability Scale (SUS) score of 82.5, which is included in the "Excellent" category.

The main contribution of this research lies in the application of the CPM method into applications that are tailored to the real needs in the field, as well as the provision of applicability and ready-to-use solutions for the medium-scale construction industry. As such, the app not only has technical value, but also has a direct impact on improving overall project management performance.

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