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Analysis and Application of Construction Management in The Waled-Ciledug BTS Road Reconstruction Project

Radja Syahidir Firdaus[1]
Universitas Swadaya Gunung Jati, Indonesia
Email: radjasy01@gmail.com

Herry Hermawan[2]
Universitas Swadaya Gunung Jati, Indonesia

ABSTRACT

Project planning, cost, time, quality, contract administration, and safety management are the regulated aspects of construction in construction management. As a result, project objectives cannot be realized without competent construction management. Planning, execution, and control are the three main functions of construction management. All human and other project resources are managed through these three processes: planning, execution, and review. The purpose of this study aims to determine construction time management, find out how long the project duration will take if using CPM and PERT methods, analyze CPM and PERT on the comparison of planning time. The approach method used is a qualitative technique that involves collecting field data that will be used as information for the research topic. The researcher uses the CPM and PERT methods as a tool in projects related to a management in planning and control in the project. The CPM and PERT methods are used to figure out the duration of the project required and also identify the types of critical work in the project. Based on the analysis conducted, the CPM method only requires 100 days and the PERT method 100.48 days. Using the CPM method produces a time efficiency of up to 20 days compared to the PERT method of only 19.52 days. From the results obtained, the critical path of the two methods is A, B, C, D, and also the non-critical path is E, the duration is faster than the previous plan schedule which is 120 days.

Keywords: CPM; PERT; Project Control

INTRODUCTION

Management and technology in the construction business are the focus of construction management. Project planning, cost, time, quality, contract administration, and safety management are the regulated aspects of construction in construction management (Astika & Dwirandra, 2020; Boonpheng et al., 2021; Bradley et al., 2019; Navimipour & Soltani, 2016; Yan et al., 2016). As a result, project objectives cannot be realized without competent construction management. Management is the process of planning, organizing, and controlling the efforts of organizational members and the process of using organizational resources to achieve a predetermined organization. (Nurhikmah, 2024).

According to (Levy & Sidney M., 2002; Winch GM. & John Wiley & Sons., 2012), construction management includes various activities starting from the implementation of the work and ending with the development of results. Management is the process of setting goals, developing strategies, allocating resources, and monitoring performance. According to (Winch GM. & John Wiley & Sons., 2012), construction management includes various activities starting from the implementation of the work and ending with the development of results. One way to cope with construction demands is through construction management. According to (Nisarg Arvindbhai & Solanki, 2020; Onana, 2018), construction management integrates the planning, design, and construction phases of projects into one activity.

A management team consisting of owners, managers, and design companies is tasked with carrying out these responsibilities. This team can also include funding agencies and/or contractors. Team members enter into contractual agreements to reduce conflict and increase responsiveness within the group. The fact that one company – a construction management company – is involved in a project from start to finish makes the construction management process different from the others. The reason construction management is adopted is because it offers several benefits over traditional techniques. According to (Adekunle et al., 2022), these benefits can be evaluated in terms of price, quality, and time.

To achieve construction management goals, we must think about things like time, cost, and quality of work, while still paying attention to worker safety and the environment. You can't separate these elements because they're all interconnected. To control these three limitations, equipment is essential. As a result, the achievement of business goals, such as profits, reputation, and professionalism, is greatly influenced by equipment management. These goals can be assessed based on the organization's capacity to control costs, complete tasks on schedule, and produce goods that meet quality standards. (Winch GM. & John Wiley & Sons., 2012).

Good resources, availability of materials and equipment, natural conditions, weather, and other variables affect the progress of the project, which in turn affects the need for good planning, scheduling, and management during the execution of the project. These factors can affect the project's execution schedule as well as its completion schedule, causing the planned time to exceed the predetermined period. When problems arise during the course of a project, it can affect how the project is run. When the process fails, it indicates that the initial goal was not achieved, leading to a loss of resources.

Good management, according to management theory, requires directing limited resources (time, energy, money, etc.) to achieve the desired results in the least amount of time and effort. Management effectiveness and efficiency are the two main measures used to evaluate its success. Efficiency is completing an activity correctly, while effectiveness is choosing a goal. Therefore, it is imperative that everything must be carried out with maximum effectiveness and efficiency, ensuring accuracy, speed, affordability, and safety. (Zhang et al., 2017).

The implementation of work on the project requires adequate human resources, and also requires good management. The CPM (Critical Path Method) and PERT (Project Evaluation and Review Technique) methods are tools in projects related to a management in planning and control in the project. Project planning on construction, time and cost is very optimized and most importantly to know, the thing that must be done for time and cost optimization is to create a network, look for activities that have critical and non-critical paths in the project and to calculate the duration of the project.

The CPM method is a network of work research that optimizes project costs by shortening or extending the completion time. The CPM approach, which is very popular in project management, is a set of phases and methods for planning and control that utilize the principle of networking. The CPM approach ensures that all project requirements, including the time required to complete them and the relationships between the resources used, are recognized early on before any work is performed. By reducing the overall duration of the project, the CPM approach optimizes the total cost of the project. This is achieved by providing analytical findings on the project's activity network. CPM, or Critical Path Method, is sometimes known as the Critical Path Method because of the way it describes critical routes using arrow graphs. Of all the systems that use the concept of networking, CPM is the most popular because it works very well for project planning and supervision. Setiawati et al. (2017) said that CPM can optimize project costs by reducing or extending project time. The CPM strategy includes network diagrams, relationships between symbols and sequence of activities, critical paths, activity grace periods and activity schedule limits.

The CPM (Critical Path Method) method, sometimes known as the Critical path method because of the way it depicts the critical path using arrow graphs. To identify the activities that make up a project and provide an estimate of its completion time, project managers often use the PERT (Project Evaluation and Review Technique) method, or project evaluation and review technology. PERT is a networking technique that connects various project operations and minimizes work delays, which can lower overall project completion time. PERT analysis is very helpful in discussions with clients as well as discussions involving project implementation. This can be applied to increase self-confidence about the duration to be chosen.(Farida et al., 2022; Trietsch & Baker, 2012) The PERT method is to identify the activities that make up a project and provide an estimate of its completion time, project managers often use PERT, or project evaluation and review technology.

PERT was first created in 1958 for project planning and management by the consulting services of Bozz-Allen and Hamilton. The fact that this approach can complete the job faster than the predetermined time makes it successful. The following are some of the advantages of using the PERT approach (Farida et al., 2022): being able to recognize the relationship between the tasks involved in a project, being able to determine an alternative implementation time in the event of a delay in work that is an obstacle, being able to determine what steps can be taken to facilitate the smooth operation of the project, being able to determine how long it will take to complete the work.

PERT, or prediction of the likelihood of project completion using statistical techniques, is probabilistic (normal distribution or Z). Three PERT technique estimates, which are used to provide a grace period for a set project duration, are used to characterize the probabilities for each project activity. (Trietsch & Baker, 2012) The three estimates consist of: 1. Optimistic duration time or optimistic time. This estimate is based on the assumption that work can go on as usual. The project will complete its work at the fastest pace during this period. Currently, α is the most commonly used notation, 2. Most likely time. To provide a typical or most likely (realistic) duration, the estimate requires a period of project activity that is repeated under the same circumstances. The modern standard symbol is m, 3. Pessimistic duration time or time is most likely. This estimate is based on the idea that obstacles will prevent project activities from going as planned. The project will take the longest to complete this time.

RESEARCH METHODS

In this study, analysis using project data and direct observation on the Waled-Ciledug Road Section, a qualitative research approach was used. The reconstruction project of the 3.38 km Waled-Ciledug Road section starts from STA 0+000 and ends at STA 2+300. Based on S-curve data, the implementation of this project will take 120 calendar days. The West Java Provincial Budget for the 2024 Fiscal Year provides funds for the Waled-Ciledug Road Reconstruction Project, with a total value of Rp. 6,368,846,061.73 in accordance with (Six Billion Three Hundred Sixty-Eight Million Eight Hundred Forty-Six Million Sixty-One Thousand Seventy-Three Rupiah). The construction of this road is located in Cirebon Regency. CV. Haka Mubarok as the implementing contractor of this project.

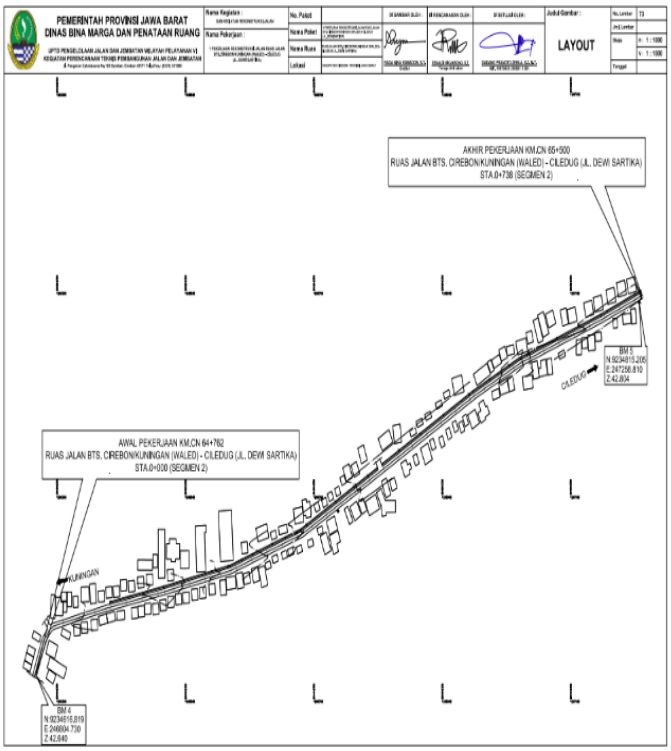

Figure 1. Project Location

The understanding of the methods used is Qualitative techniques that involve collecting field data that will be used as information for research topics, Qualitative approaches involve collecting and reviewing the literature on planning and analysis of calculations. The most tactical method of collecting data in research is the data collection procedure. The following data collection strategies can help researchers get the necessary data while still following the data standards that have been set, including secondary data because it is data that will later be processed, the data is in the form of rab, images and S curves.

The implementation of the investigation methodically and systematically is the stage of this research. In short, this stage of research aims to describe the processes involved in the implementation of research, with the aim of directing research more appropriately during the research. The first step in conducting research is to get started. This step is completed before moving on to other tasks, such as finding the name of the research to be done. A summary of the research conducted based on a predetermined title must be prepared as part of the final project research preparation stage. Next, find the research location and look for the problem in the title.

The data collection done for this project is to search for the necessary secondary data. Thus, this study utilizes secondary data from the project data, namely the S curve time schedule, which will then be analyzed using PERT and CPM methods for work network planning. Now is the time to apply the CPM and PERT methodologies, developed at this stage, to define the work network, the crucial trajectory, and the comparison of the length of the work implementation activities. Data for this stage should have been collected from the implementing contractor. A crucial network of work and trajectories can help identify which tasks are most likely to be delayed and which are not. At this point, the research findings will be examined to determine the results of the project scheduling analysis using the CPM and PERT methodologies by comparing the researchers' calculations with the data collected from the project. After data analysis and discussion, recommendations and conclusions are generated as the culmination of the final project research, which serves as a benchmark for academics in terms of policy. and offer recommendations that lend credibility to the study.

The process of handling the collected data is called data analysis. This study uses the CPM and PERT methodology to analyze the duration of implementation. Data processing through manual calculations is the next step after gathering all the required information. Identify Activities, at this stage, the scope of the project is evaluated and the activities that make up it - the individuals or groups of related activities are categorized. Determine the Sequence of Activities, establish or restructure relationships between various operations. The initial elements are rearranged in this stage according to the relevant dependency logic. Creating a Network Diagram, creates a network diagram that shows the relationships between all the actions in this stage that have been grouped into a single unit in a sequence that makes sense in terms of dependencies.

Assign a Time for Each Activity, outlining the duration of each task next defining the scope of the project. When assessing activity duration, CPM and PERT differ significantly. If the CPM uses three estimation numbers the optimistic time, the most likely time, and the pessimistic time, then the PERT uses only one estimate number. Identify the critical path on the network diagram. At this point, the forward and backward calculations are done using a pre-compiled network diagram. Flot is calculated and critical routes are determined from both calculations.

RESULTS AND DISCUSSION

In the analysis of this study, two methods were used, namely, the CPM (Critical Path Method) and PERT (Project Evaluation and Review Technique) methods are a tool in projects related to management in planning and control in the project. First of all, the CPM and PERT methods define the sequence of activities to generate a network diagram. Furthermore, the duration of each activity is included, and finally a forward and backward count is carried out to determine the critical trajectory and length of time needed to complete the Waled-Ciledug Road Reconstruction Project. The data for this study uses RAB and S Curve to be used as material to make a project schedule.

REKAPITULASI
DAFTAR KUANTITAS DAN HARGA

Kegiatan : **Penyelenggaraan Jalan Provinsi**
Sub Kegiatan : **Rekonstruksi Jalan**
Nama Paket : **1 Pekerjaan Rekonstruksi Jalan Ruas Jalan Bts, Cirebon/Kuningan (Waled) - Ciledug (jl. Dewi Sartika)**
Lokasi : **Kabupaten Cirebon**
Prop./ Kab./Kota : **Jawa Barat/Kabupaten Cirebon**

No. Mata Pembayaran	Uraian	Jumlah Harga-Harga (Rupiah)	Jumlah Harga + PPN 11%
a	b	c	d
DIVISI 1. UMUM		79.223.113,61	87.937.656,11
DIVISI 2. DRAINASE		-	-
DIVISI 3. PEKERJAAN TANAH DAN GEOSINTETIK		-	-
DIVISI 4. PEKERJAAN PREVENTIF		-	-
DIVISI 5. PERKERASAN BERBUTIR			
5.1.(3)	Lapis Pondasi Agregat Kelas S	177.010.827,66	196.482.018,70
DIVISI 6. PERKERASAN ASPAL			
6.1 (2a)	Lapis Perekat - Aspal Cair/Emulsi	110.850.779,90	123.044.365,69
6.3(5a)	Laston Lapis Aus (AC-WC)	2.505.569.391,72	2.781.182.024,81
6.3(6a)	Laston Lapis Antara (AC-BC)	2.529.854.888,40	2.808.138.926,12
DIVISI 7. STRUKTUR		-	-
DIVISI 8. REHABILITASI JEMBATAN		-	
DIVISI 9. PEKERJAAN HARIAN & PEKERJAAN LAIN-LAIN			
9.2.(6a)	0 Patok Kilometer	1.854.027,00	2.057.969,97
9.2.(6b)	0 Patok Hektometer	5.302.242,00	5.885.488,62
DIVISI 10. PEKERJAAN PEMELIHARAAN KINERJA			
10.1.(4)	Perbaikan Lapis Fondasi Agregat Kelas A	161.035.331,76	178.749.218,25
10.1.(9)	Perbaikan Campuran Aspal Panas	166.809.552,66	185.158.603,45
10.1.(19a)	Pengecatan Patok	189.000,00	209.790,00
JUMLAH PENAWARAN		**5.737.699.154,71**	**6.368.846.061,73**

Terbilang Enam Milyar Tiga Ratus Enam Puluh Delapan Juta Delapan Ratus Empat Puluh Enam Ribu Enam puluh Satu 73/100 Rupiah.

Figure 2. RAB

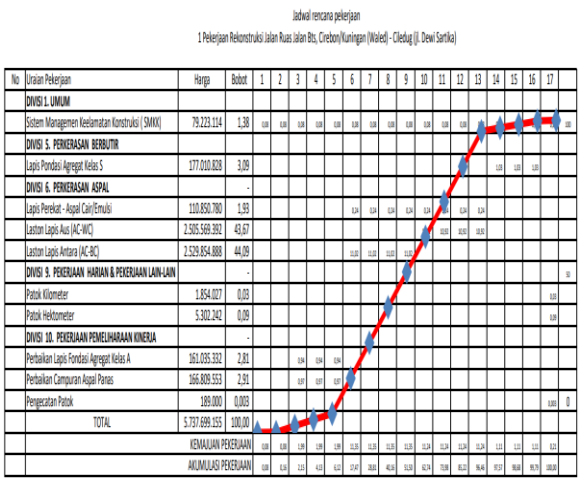

Figure 3. S Curve

After looking at the RAB and S Curve, the identification of the work and duration for the project scope is made.

NO	JOB	DURATION
1	General (Mobilization)	10
2	Grained Pavement	20
3	Asphalt Pavement	60
4	Daily Jobs & Other Jobs	10
5	Performance Maintenance Work	20

Figure 4. Occupation and Duration

Showing the description of the work and duration based on the S curve data in the Attachment of the Waled-Ciledug Road reconstruction project. Then the data is sorted by order of work and type of activity.

No	Work	Symbol	Duration (Day)	*Predeccessor*	*Successor*
1	General (Mobilization)	A	10	-	B,E
2	Granulated Pavement	B	20	A	C
3	Asphalt Pavement	C	60	B	D
4	Daily Jobs & Miscellaneous Jobs	D	10	C	-
5	Performance Maintenance Work	E	20	A	-

Figure 5. Relationships between jobs

Show a description of what work was done in this study and show the code, duration of activities, predecessor activities. The project is divided into many work activities, each of which is programmed to facilitate the creation of a network diagram of the work network from the results of scheduling analysis using the CPM technique of dependency logic relationships.

CPM Method Dependency Analysis

Activity On Arrow (AOA) is a cpm and pert method working network. A work network model can be created from the results of the analysis of the relationship between activities using S curve data.

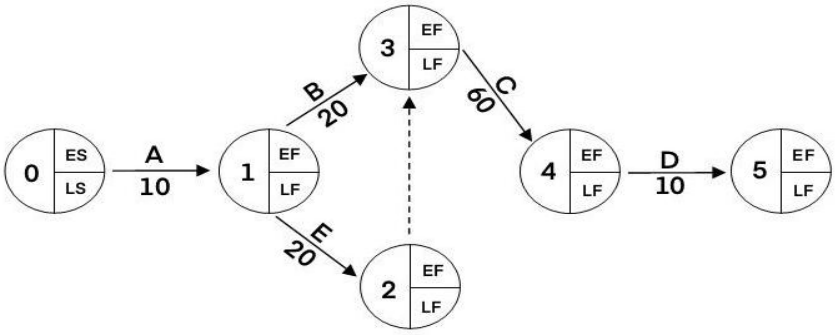

Figure 6. Forms of cpm and pert work networks

The AOA (activity on arrow) model working network the activity and its length are shown on the arrow, and the event with the activity number, ES (initial list), EF (end list), LS (late start), and LF (late finish) is shown in a circle. The results of the optimal time CPM analysis can be done in two ways by forward pass from the initial activity to the final activity and the backward pass from the final activity to the initial activity. For forward pass analysis to determine the end time of the completed series of actions, forward count analysis is performed. The counting analysis starts with a value of 0 sorted to the end, and the largest value is selected if there are more than 1 occurrence.

Activity	Duration	ICE	EF
A	10	0	10
B	20	10	30
C	60	30	90
D	10	90	100
E	20	10	30

Figure 7. Forward pass analysis results to determine the EF value

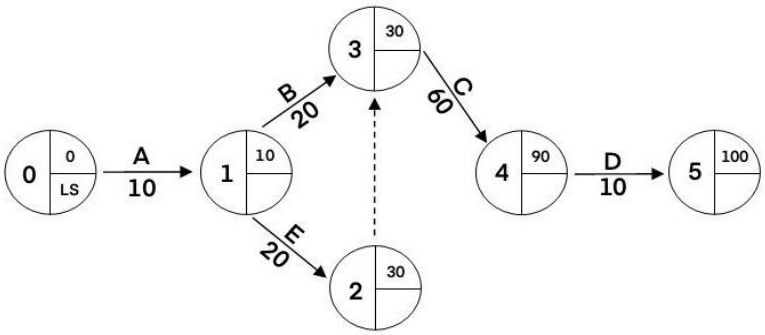

Figure 8. Forward Count Analysis Network

Based on the results of the forward pass analysis, the Waled-Ciledug Road reconstruction project took 100 working days to complete. Forward pass analysis network configuration. Backward pass analysis is the initiation of a sequence of actions determined through the use of countdown analysis. By obtaining the final score and sorting it from the beginning, the countdown analysis is carried out starting from the end. The smallest number is selected if there are two or more-time events.

Activity	Duration	L.S	LF
A	10	0	10
B	20	10	30
C	60	30	90
D	10	90	100
E	20	10	90

Figure 9. Backward Pass analysis results to determine the LS value

The results of the backward pass analysis were used to determine the LS value. Based on the results of the backward pass analysis, the Waled Ciledug road reconstruction project took 100 working days to complete.

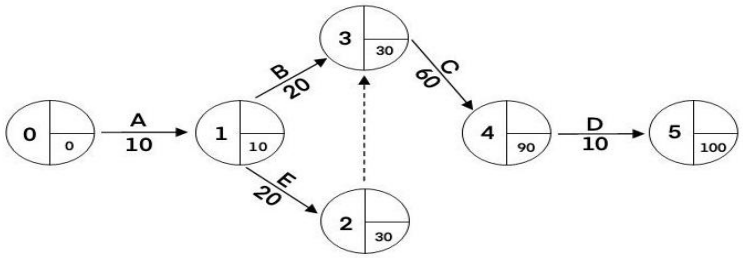

Figure 10. Backward Pass Analysis Network

The total float is the amount of time that can pass between tasks without affecting the final completion date of the project.

Activity	Duration	ICE	E.F	L.S	LF	T.F (LF-ES-D)
A	10	0	10	0	10	0
B	20	10	30	10	30	0
C	60	30	90	30	90	0
D	10	90	100	90	100	0
E	20	10	30	10	90	60

Figure 11. Results of Total Time Calculation Analysis

The results of the forward pass analysis to determine the EF value. The results of the analysis of the total time calculation can be seen that activities A, B, C, and D have a Total Float (TF) value of 0, which indicates that these activities do not have a grace period so they are considered critical activities. Activity E, on the other hand, has a TF value which indicates that this activity has a grace period, based on the normal duration of the Waled-Ciledug Road reconstruction project.

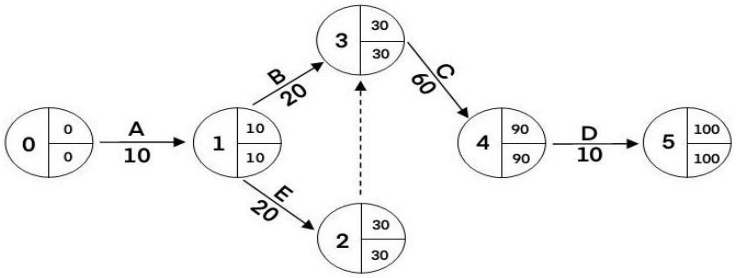

Figure 12. CPM (Critical Path Method) network

Form network planning using the CPM approach. Activities are positioned on the arrows, and the circle represents events with activity numbers and values for ES (Early Start), EF (Early Finish), LS (Late Start), and LF (Late Finish). Similar to action A on the arrow, event 0 occurs at the beginning of activity A, event 1 at the end, and so on until activity O. The analysis findings show that the event value is equal to ES = LLS and EF = LF, which means that, with a total time of 100 days, the critical path consists of A, B, C, and D, while the non-critical path is E. Dummy relationship, such as E, B, and C in the previous image, show a dependency relationship and have no duration of zero.

The results of the PERT analysis have three estimated time required for each activity in a network-based project scheduling approach known as "pert analysis": optimistic, likely, and pessimistic forecasts. These three estimates can be used to determine the usual start and end times for an activity or event, as well as the likelihood of completing the project by the deadline. Identifying relationships between activities involves defining the activities that make up a project, breaking them down into individual activities or related task groups, and organizing activities in between. from the findings of the Pert technique on logical dependency connection scheduling analysis.

No	Activity	Symbol 1	Optimistic Time (a)	Most Probable Time (m)	Pessimistic time (b)	Predecessor	Success Sor
1	General (Mobilization)	A	7	10	13	-	B,E
2	Granulated Pavement	B	18	20	24	A	C
3	Asphalt Paving	C	59	60	63	B	D
4	Daily Jobs & Miscellaneous Jobs	D	8	10	12	C	-
5	Performance Maintenance Work	E	20	20	22	A	-

Figure 13. PERT Method Dependency Analysis

This table shows what work activities were carried out in the research and shows the code, duration, and preceding activities. Each job's PERT time analysis has three estimated time required for each task in the Pert network-based project scheduling analysis: optimistic, most likely, and pessimistic. These three-time estimates can be used to determine the usual start and finish times for a task or flap event, as well as the possibility of completing the project before the deadline. The results of the analysis are based on three estimated times for start and finish times.

Activity	Estimation activity time (a+4m+b 6	Early Start	Early Finish	Late Start	Late Finish	Late time limit activity	Deviation standard (S) $\frac{1(b-a)}{6}$	Variance $V=S^2=\left[\frac{b-a}{6}\right]^2$
Project	100.48							
A	10.16	0	10.16	0	10.16	0	1	1
B	20.33	10.16	30.49	10.16	30.49	0	1	1
C	60.33	30.49	90.82	30.49	90.82	0	0.66	0.44
D	9.66	90.82	100.48	90.82	100.48	0	0.66	0.44
E	20.33	10.16	30.49	10.16	30.49	0	0.33	0.11

Figure 14. Results of Time Analysis According to Pert Method Activities

The expected time of activity is based on three time-forecasts optimistic, most likely, and pessimistic. The value of the initial activity time and the value of the final activity time are obtained from the sequence of activities based on the estimated value of the activity time analysis.

$$Z = \frac{T(d) - TE}{S}$$

Project Variance = ∑ (activity variance on critical paths)

Project Variance = ∑ (1+1+0.66+0.66+0.33)

Project Variance = 3.65

S = Project standard deviation

S = √Project Variance

S = √3.65

S = 1.91

Z = Normal distribution value

$$Z = \frac{(\text{Timeout} - \text{the amount of critical trajectory time})}{S}$$

$$Z = \frac{(120 - 139.33)}{1{,}91}$$

Z = 0.21

z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.5	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
-0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641

Figure 15. Normal Z distribution table

The probability of 0.5793 comes from the normal Z distribution table, which has a value of 0.21. This shows that there is a 57.93% chance of completing the project in 120 days or less. The PERT method work network is a work network including the trajectory of activities, the duration of the implementation calculated from three estimated times, and the sequence of activities during the implementation of the project that has been analyzed using formulas.

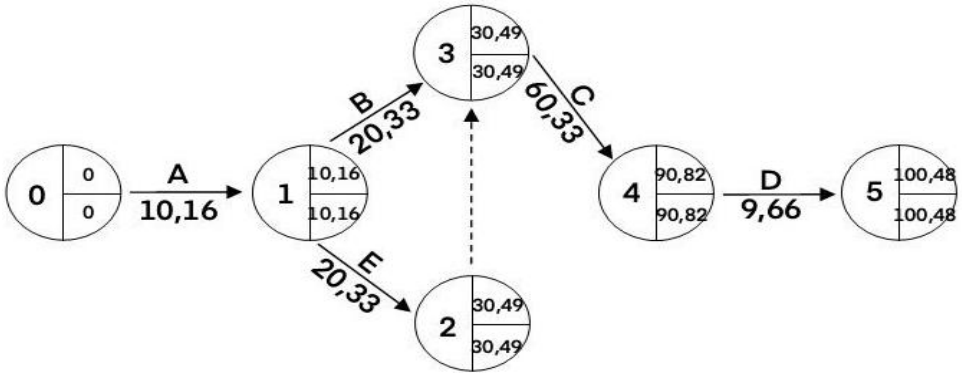

Figure 16. Pert method working network diagram

Network planning using the PERT approach. Activities are placed on arrows, and events with values of ES (Early Start), EF (Early Finish), LS (Late Start), and LF (Late Finish) and activity numbers are represented by circles. With a total of 100.48 days, the critical path is A, B, C, D, and the non-critical path is E, according to the results of the analysis of the event value with the same number, namely ES = LLS and EF = LF. Dummy relationships, such as B and E, which illustrate the relationship of activity dependence and dummies having no duration or zero, are also depicted in the figure above.

The time comparison of the CPM and PERT methods is based on the results of the examination of the project planning techniques mentioned above and the initial scheduling approach for the Waled-Ciledug Road reconstruction project for 120 days. Furthermore, the author can make a comparative evaluation of each approach regarding its application, dependency logic, crucial project implementation path, and overall length.

NO	Description	Duration
1	CPM uses one time estimate, using the concept of AOA (Activity On Arrow) logical relationship FS (finish to start)	based on the results of the analysis with the critical path obtained using the CPM method, namely activities A, B, C, D with a time of 100 working days
2	PERT uses three time estimates, namely optimistic time,	the results of the analysis with the critical path obtained using PERT
	most likely time, and pessimistic time. Using the AOA (Activity On Arrow) concept, the logical relationship FS (finish to start)	the same as the CPM method but different from the duration obtained, which is 100.48 working days. Based on the Z table of normal distribution with a value of 0.21, the probability is 0.5793, meaning that there is a 57.93% chance of completing the project within 141 weeks or less.
3	In the field	Based on the BTS Road Section Reconstruction Project Planner's time (Waled-Ciledug), it is 120 working days.

Figure 17. Results of Project-Time Results Comparison

Based on the comparison of the CPM and PERT methods, it is clear that the CPM method uses a 100-day work schedule and uses a single time slot for each activity, while the PERT method uses the logical relationship of FS between the activities indicated by the arrows to generate critical trajectories A, B, C, and D. A total of 100.48 manpower days are required, in contrast to the three-time estimates of the PERT method – optimistic, likely, and pessimistic – and the logical relationship of the FS tasks indicated by the arrows that generate critical trajectories A, B, C, and D. All of these things show how the analysis carried out in this study compares different time periods. Since CPM requires only one time estimate, whereas PERT requires three-time estimates, CPM is clearly superior in terms of duration. It is crucial for contractors to pay close attention to the critical pathways to maintain the work according to the duration of the planning.

CONCLUSION

The use of CPM and PERT techniques in the Waled-Ciledug Road construction project has led to several key conclusions. By employing the work network from the CPM approach, multiple tasks such as performance maintenance and granular pavement can be completed simultaneously, reducing the project timeline or accelerating completion. Critical paths were identified using the CPM method, with the longest critical path resulting in a total project duration of 100 working days. A comparison of the initial project plan, which was set at 120 days, showed that the CPM method completed the project in 100 days, while the PERT method took 100.48 days due to the use of three-time estimates—optimistic, most likely, and pessimistic-indicating a longer duration for PERT. This finding aligns with previous studies, confirming that the CPM method results in a shorter completion time compared to the PERT method. Based on these findings, it is recommended that critical path approaches like PERT and CPM be used to optimize duration planning and as tools for time control. The reconstruction project of the BTS road section can be expedited by applying these methods, and project scheduling techniques tailored to the project's specific characteristics should be implemented. The CPM and PERT approaches are valuable for organizing and predicting project duration in the Waled-Ciledug Road reconstruction.

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