Analysis of Project Acceleration Implementation Using the CPM and PERT at Lettu Imam Building

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Abstrak

Pelaksanaan proyek konstruksi pada umumnya memiliki batas waktu yang telah ditentukan. Untuk mencapai batas waktu tersebut diperlukan perencanaan dan pengendalian. Perencanaan dapat menentukan pekerjaan apa yang perlu dilakukan dan kapan dilakukan, sumber daya apa yang dibutuhkan, dan risiko apa yang mungkin timbul. Target kegiatan yang jelas dapat diidentifikasi untuk setiap kegiatan. Penelitian ini menganalisis Proyek Pembangunan Gedung Lettu Imam di Kompleks Perkantoran OPD Kabupaten Pasuruan. Penelitian ini menggunakan Critical Path Method (CPM) untuk menentukan item pekerjaan yang melewati lintasan kritis dan Project Evaluation and Review Technique (PERT) untuk menentukan probabilitas keberhasilan proyek. Hasil analisis dengan menggunakan Critical Path Method terdapat 14 item pekerjaan yang berada pada lintasan kritis A1 - A2 - A3 - B1 - C1 - C2 - C3 - C4 - C5 - C6 - C7 - C8 - C9 - D1. Dan hasil analisis menggunakan Project Evaluation and Review Technique memiliki probabilitas penyelesaian proyek sebesar 89,43% - 99,37%, dengan durasi pelaksanaan proyek selama 162 - 164 hari.

Kata kunci: *Jalur Kritis, Metode Jalur Kritis, Perencanaan, Probabilitas, Evaluasi Proyek dan Teknik Review.*

Abstract

The implementation of construction projects generally has a predetermined time limit. To achieve the time limit, planning and controlling are necessary. Planning can determine what work needs to be done and when it is done, what resources are needed, and what risks may arise. Clear activity targets can be identified for each activity. The case study in this research is Lettu Imam Building Construction Project in the OPD Office Complex of Pasuruan Regency. This study uses the Critical Path Method (CPM) to determine the work items passed through the critical path and the Project Evaluation and Review Technique (PERT) to determine the probability of project success. The results of the analysis using the Critical Path Method are 14 work items that were on the critical path A1 - A2 - A3 - B1 - C1 - C2 - C3 - C4 - C5 - C6 - C7 - C8 - C9 - D1. And the result analysis using Project Evaluation and Review Technique has a project completion probability of 89.43% - 99.37%, with the project implementation duration being 162 - 164 days.

Keywords: *Critical Path, Critical Path Method, Planning, Probability, Project Evaluation and Review Technique*

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1. INTRODUCTION

The fundamental obstacles to building and maintaining the infrastructural networks necessary for economic stability are being addressed by Indonesia. Infrastructure network management and administration are becoming increasingly concerned due to deteriorating infrastructures, rising costs, resource scarcity, productivity, rapid regional expansion, environmental concerns, and expansive growth. [1].

To accomplish the specified goals, the project combines a variety of resources (labor, finances, tools, infrastructure, and support services) under a single company. [2].

A project consists of several transient tasks with time constraints, precise resource allocations, and predetermined goals. The task that will help the company is defined and chosen as part of the project. Time and money constraints place a restriction on project activity. Projects have a start and conclusion point, are non-routine, multi-activity with different intensities, have short cycles, and are subject to finance limits. [3].

Projects are temporary activities that aim to produce products with clearly defined criteria with limited resource allocation and lasting within a certain period, where the costs required to complete a project consist of direct and indirect costs. A large number of activities in a project and the relationship between activities in a complex project causes the need for a project implementation scheduling plan so that in project implementation, there is no difficulty in meeting the agreed conditions in terms of the project cost, project duration, and quality of the final result. Scheduling for complex projects is not easy, requires special skills, and requires time and effort. Optimal scheduling allows optimal cost and duration to be obtained [4].

The more activities whose completion is not by the initial plan, the greater the total time required to complete the project. Therefore, sound planning is needed in compiling the duration of each work, the order of work items, and determining each item that should not be delayed [5] .

However, in the implementation process, conditions in the field are often unpredictable, so the possibility of delays is also high. In this case, it is known that the construction process of this building is experiencing delays. Where the construction should have started in May but in fact, it was carried out in June. As a consequence, the completion of this project was delayed, the project was required to be completed in November, but this construction project was completed in December. In addition, this project also found a volume shortage due to a lack of time. This volume deficiency was in the ceiling painting work, which resulted in the contractor being required to pay a fine of 89 million rupiahs.

There are impacts that often occur due to delays in construction projects, namely additional costs, where the amount is greater than the costs estimated at the beginning of the project, additional time required to finish the project, late payments, rescheduling of the specified time due to disruptions. and problems that arise, the

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impact on the company's reputation, as well as the loss of productivity and labor efficiency in completing projects [6].

Another study, using a combination of CPM and PERT methods, is to find the critical path and calculate the probability that it can be achieved. However, in this study, a combination of CPM and PERT is used to find the critical path and determine the probability of completion within the desired time. So that it can be adjusted according to needs or by the conditions of the completion time, bearing in mind that events in the field are often unexpected. This study uses the help of GeoGebra software to determine normal distribution values so that the results obtained will be more accurate than the normal distribution tables commonly used, considering that normal distribution tables have limited data presentation. In addition, the fundamental difference from previous research is the difference in research locations which have their own challenges and constraints.

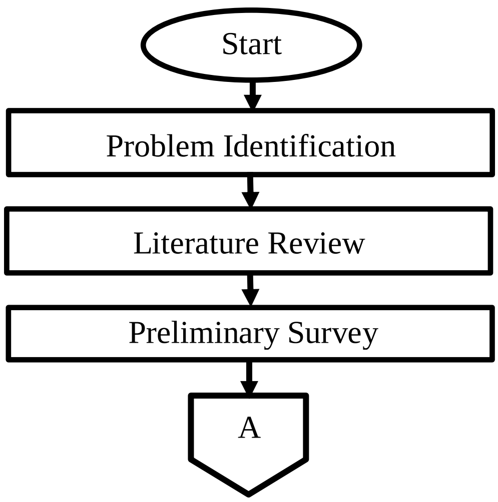
The Critical Path Method (CPM) network is used for projects that are repetitive in nature or for projects for which it is possible to predict costs and the amount of time needed to complete each activity with reasonable precision. The Critical Path Method (CPM), for instance, is advantageous for building projects. However, it is not appropriate for initiatives involving research and development [7].

A method of management science for project planning and control is program evaluation and review. Instead of making a schedule, PERT's goal is to examine the project network. In the application, PERT uses three times estimations that are optimistic, most likely, and pessimistic to deal with the durational uncertainty [8].

The Project Evaluation Review Technic (PERT) method uses a probabilistic approach, while the Critical Path Method (CPM) uses a deterministic approach for project scheduling and evaluation. Despite a little difference, the CPM-PERT approach can be used to analyze project duration because it serves the same purpose [9].

2. RESEARCH METHOD

The stages of this research are illustrated by the flow chart as follows:



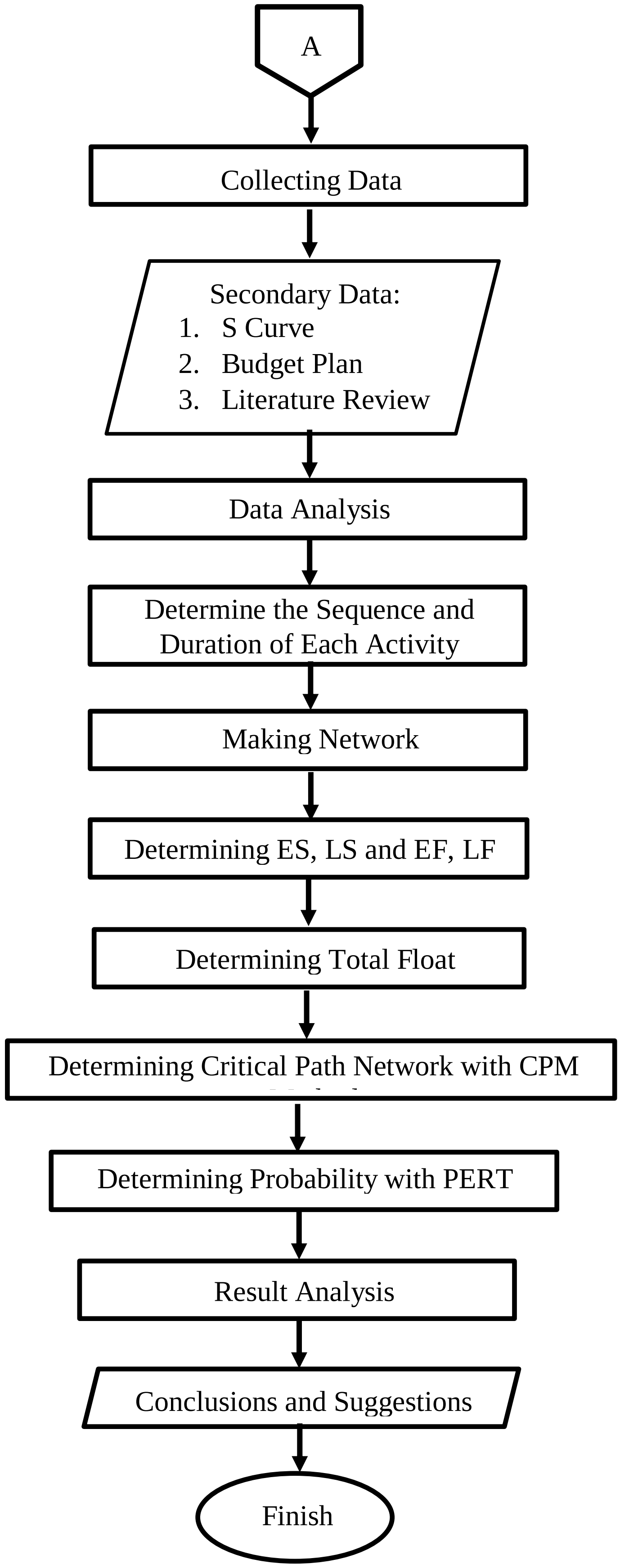


Figure 1 Flow Chart

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2.1 Type of Research

This type of research method is quantitative. The method carried out is in the form of alternative planning of the optimal duration of the project using the CPM and PERT method based on data obtained from direct observations and interview in the field.

The object of this research is one of the Pasuruan Regency Organisasi Perangkat Daerah (OPD) Office Building named Lettu Imam Building and the subject of this research is project time control by the CPM and PERT method.

2.2 Research Variable

The purpose of this study was to determine the time of acceleration of the implementation of the construction of the Lettu Imam Building so that the variables in this study were focused on the time of implementation of project activities.

2.3 Data Analysis Method

Research must be carried out systematically with a clear and orderly sequence to obtain the expected goals and results. Therefore, the implementation of this research is divided into several stages as follows:

1. Literature Study

Before starting the research, a literature study was conducted to deepen knowledge about the topic by reading several books, lecture materials, journals, and references related to the research topic.

2. Data Collection

At this stage, the project data collection needed to support the research was carried out. The data needed is the schedule of project activities for the Lettu Imam Building. These data were obtained from PT. Cipta Karya Multi Teknik who worked on the project.

The data was collected through direct surveys at the project site. Interviews were conducted directly with several project experts. The data is supporting data related to constructing the Lettu Imam Building construction project and some literature. The data required are as follows:

1) S Curve
2) Budget Plan
3) Shop Drawing

3. Determining Research Object

To determine the object of research, it is necessary to collect data. Then identify the problem to be studied. In this study, the object in question is the acceleration of the duration of the implementation of the Lettu Imam Building construction activity.

4. Research Implementation

The secondary data are collected and then researched for the acceleration of duration planning on the Lettu Imam Building construction project using the CPM and PERT. The estimated completion time of a project can be determined by:

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a. Single duration estimate (CPM approach).
b. Triple duration estimate, which is a time estimation method based on three kinds of duration (PERT approach).

1. Critical Path Method (CPM)

In the process of identifying the critical path, some terminology and calculation formulas are known as follows:

a. ES (Earliest Start Time)
b. EF (Earliest Finish Time)
c. LS (Latest Allowable Start Time)
d. LF (Latest Allowable Finish Time)
e. D (Duration)

In identifying the critical path used, a method called forward count. The following are the rules or rules in compiling a network:

a. New activity can be started when the activity that precedes it has been completed, excepting for the initial activity.
b. The earliest completion time of an activity is the same as the earliest start time, plus the period of the activity concerned.

$$EFij = ESij + dA \quad (1)$$

c. The earliest start time of an activity is equal to the earliest finish time of the preceding activity with the most earliest start times when there are two or more prior activities that combine.

The backward computation is intended to determine the latest time or date that each activity can start and end without delaying the overall project completion period, which has been generated from the forward count. The countdown begins from a network's far right (last day of project completion). The following are the rules or rules for compiling a network in a countdown:

a. $LSij = LFij - dA$ (2)
a. ESij = LSij = 0
b. LF = EF
c. TF = 0.

A bold line indicates the presence of the critical path. If the network has only one starting point (initial node) and one endpoint (terminal node), then the critical path also means the path with the longest completion times, and that amount of time is the fastest project time. Sometimes find more than one critical path in a network. The total float can be calculated by formula as follows:

$$TF = LETj - EETi - Dij \quad (3)$$

Total Float (TF) indicates how long an activity may be delayed so as not to affect the project completion time. The duration of an activity can be written as the amount of time obtained if all previous activities started as early as possible and subsequent activities started as late as possible. This float is owned by all activities that are on the path in question.

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2. Program Evaluation Review Technique (PERT)

This method assumes that there are many factors that can affect the estimation of the 3 types of duration below:

a. to (a) = Optimistic duration
b. tm (m) = Most likely duration
c. tp (b) = Pessimistic duration

The PERT step to determine the probability value of project activities, then the formula for determining the estimated time of activity is as follows [10]:

a. Determining Expected Time Period (te).

Expected Time Period can be calculated by the following equation:

$$Te = \frac{a+4m+b}{6} \tag{4}$$

Information:

Te = Expected duration
a = Optimistic duration
m = Most likely duration
b = Pessimistic duration

b. Determining Project Activity Standard Deviation

Project Activity Standard Deviation can be calculated by the following equation:

$$S = \frac{1}{6}(b-a) \tag{5}$$

Information:

S = Standard Deviation
a = Optimistic duration
b = Pessimistic duration

c. Determining Project Activity Variance

The variance can be calculated by the following equation:

$$V(te) = S^2 = \left[\frac{b-a}{6}\right]^2 \tag{6}$$

Information:

V(te) = Variance
S = Standard Deviation
a = Optimistic duration
b = Pessimistic duration

d. Determining the Probability

The probability can be calculated by this following equation:

$$Te = \frac{T(d)-TE}{S} \tag{7}$$

Information:

z = Probability
T(d) = Target completion schedule
TE = Expected project completion time
S = Standard deviation

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3. RESULTS AND DISCUSSION

3.1 Total Float Calculation

Total Float (TF) indicates how long an activity may be delayed so as not to affect the project completion time. The duration of an activity can be written as the amount of time obtained if all previous activities started as early as possible and subsequent activities started as late as possible. This float is owned by all activities that are on the path in question.

Table 1 Total Float Calculation

Nu. Code	Activity	Predecessors	Duration (Day)	Forward Computation		Backward Computation		Total Float
				ES	LS	LF	EF	TF
A	**First Floor**							
A1	Preliminary Work	-	6	0	0	6	6	0
A2	Concrete Work	A1	14	6	6	20	20	0
A3	Soil Work	A2	3	20	20	23	23	0
A4	Masonry Brick and Plaster Work	A3	14	23	23	40	37	3
A5	Wall and Floor Covering Work	A4	5	37	37	45	42	3
A6	Frame and Accessories Work	A5	5	42	42	50	47	3
A7	Ceiling Work	A6	7	47	47	57	54	3
A8	Painting Work	A7	12	54	54	69	66	3
A9	Mechanical and Electrical Work	A8	6	66	66	75	72	3
A10	Sanitation Work	A9	7	72	72	82	79	3
B	**Second Floor**							
B1	Concrete Work	A2	8	79	79	87	87	0
B2	Masonry Brick and Plaster Work	B1	12	87	88	100	99	1
B3	Wall and Floor Covering Work	B2	4	99	100	104	103	1
B4	Frame and Accessories Work	B3	7	103	104	111	110	1
B5	Ceiling Work	B4	5	110	111	116	115	1
B6	Painting Work	B5	10	115	117	127	125	2
B7	Mechanical and Electrical Work	B6	4	125	129	133	129	4
B8	Sanitation Work	B7	5	129	134	138	134	4
C	**Third Floor and Roof**							
C1	Concrete Work	B1	4	134	134	138	138	0
C2	Masonry Brick and Plaster Work	C1	10	138	138	148	148	0
C3	Wall and Floor Covering Work	C2	7	148	148	155	155	0
C4	Frame and Accessories Work	C3	5	155	155	160	160	0

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Nu. Code	Activity	Predecessors	Duration (Day)	Forward Computation		Backward Computation		Total Float
				ES	LS	LF	EF	TF
C5	Roof Work	C4	21	160	160	181	181	0
C6	Ceiling Work	C5	4	181	181	185	185	0
C7	Painting Work	C6	10	185	185	195	195	0
C8	Mechanical and Electrical Work	C7	4	195	195	199	199	0
C9	Sanitation Work	C8	4	199	199	203	203	0
D	**Connection Work**							
D1	Connection Work	A9, B7, C3	7	203	203	210	210	0

The following is the calculation procedure for work A2 in the table above.

1. Forward Computation

   ES for A2 work $= EET_2$
   $= 0 + 6 = 6$

   EF for A2 work $= ES_{2\text{-}3} + dA$
   $= 6 + 14 = 20$

2. Backward Computation

   LS for A2 work $= LF_{2\text{-}3} – dA$
   $= 20 – 14 = 6$

   LF for A2 work $= LF_{3\text{-}2} - dA$
   $= 23 – 3 = 20$

3. Total Float (TF)

   TF for A2 work $= LF – ES – dA$
   $= 20 – 6 – 14 = 0$

Through the calculations, it is known that the critical path is in activity A1 - A2 - A3 - B1 - C1 - C2 - C3 - C4 - C5 - C6 - C7 - C8 - C9 - D1 or because these activities have no slack time or total float (TF) = 0.

3.2 Network Diagram Planning

The initial step in processing data with this method is to plan a network diagram. Network diagrams can present activities, the duration of each activity, the sequence of activities, and the linkages between activities to identify which activities are on the critical path easily. Red boxes and arrows indicate critical activities in a project.

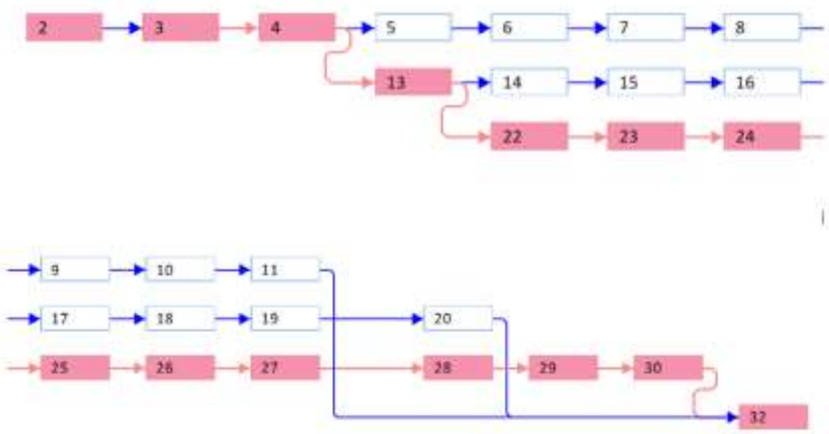

Figure 2 Network Diagram Using Microsoft Project 2019

3.3 The Value of ta, tb and tm

Based on the results of interviews with the contractor for the Lettu Imam Building construction project, the values for ta, tb and tm are presented in the following table.

Table 2 ta, tb and tm Value

Nu. Code	Activity	Optimistic Duration (a)	Most Likely Duration (b)	Pesimistic Duration (m)
A	**First Floor**			
A1	Preliminary Work	3	6	21
A2	Concrete Work	12	14	30
A3	Soil Work	1	3	7
B	**Second Floor**			
B1	Concrete Work	5	8	14
C	**Third Floor and Roof**			
C1	Concrete Work	3	4	7
C2	Masonry Brick and Plaster Work	7	10	14
C3	Wall and Floor Covering Work	4	7	12
C4	Frame and Accessories Work	3	5	10
C5	Roof Work	18	21	30
C6	Ceiling Work	3	4	7
C7	Painting Work	7	10	14
C8	Mechanical and Electrical Work	2	4	7
C9	Sanitation Work	2	4	7
D	**Connection Work**			
D1	Connection Work	3	7	14

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3.4 Activity Time (Te), Standard Deviation (S), and Activity Variation (Ve) Calculation

After determining the implementation time with the 3-time estimates above, the expected timeframe (Te) and the probability of successful project scheduling can be determined with detailed calculations below.

Table 3 Ta, S and Ve Value

Nu. Code	Activity	Optimistic Duration (a)	Most Likely Duration (b)	Pesimistic Duration (m)	Te	S	Ve
A	**First Floor**						
A1	Preliminary Work	3	6	21	15,50	0,50	0,25
A2	Concrete Work	12	14	30	24,33	0,33	0,11
A3	Soil Work	1	3	7	5,33	0,33	0,11
B	**Second Floor**						
B1	Concrete Work	5	8	14	11,50	0,50	0,25
C	**Third Floor and Roof**						
C1	Concrete Work	3	4	7	5,83	0,17	0,03
C2	Masonry Brick and Plaster Work	7	10	14	12,17	0,50	0,25
C3	Wall and Floor Covering Work	4	7	12	9,83	0,50	0,25
C4	Frame and Accessories Work	3	5	10	8,00	0,33	0,11
C5	Roof Work	18	21	30	26,50	0,50	0,25
C6	Ceiling Work	3	4	7	5,83	0,17	0,03
C7	Painting Work	7	10	14	12,17	0,50	0,25
C8	Mechanical and Electrical Work	2	4	7	5,67	0,33	0,11
C9	Sanitation Work	2	4	7	5,67	0,33	0,11
D	**Connection Work**						
D1	Connection Work	3	7	14	11	0,67	0,44
						Total Activity Variations	**2,56**

The following is the calculation procedure for work A1 in the table above.

1. Activity Time (Te) Calculation

   Te for A1 Work $= \frac{a+4 \cdot m+b}{6}$

   $= \frac{3+4 \cdot 21+6}{6}$

   $= 8$

2. Standard Deviation (S) Calculation

   S for A1 Work $= \frac{1}{6}(b-a)$

   $= \frac{1}{6}(6-3)$

   $= 0,5$

3. Activity Variation (Ve) Calculation

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$$\text{Ve for A1 Work} = \left[\frac{b-a}{6}\right]^2 = \left[\frac{6-3}{6}\right]^2 = 0{,}25$$

3.5 Probability of Achieving Target Schedule

After getting the total value of Te and the value of S, then determine the probability value. To make it easier to find the probability value, apart from using the normal distribution table, it can also be calculated with the help of the GeoGebra software.

$\mu = Te = 160$
$\sigma = S = 1{,}6$

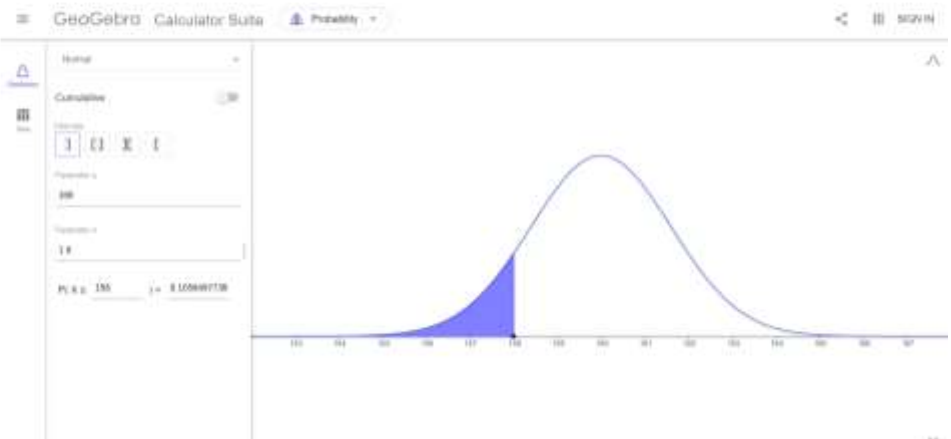

Figure 1 Probability Value Using GeoGebra

Based on the results of probability calculations using geogebra software, the probability value that the project can be completed in 158 days is 0.1056 or equal to 10.56%. The probability of the desired duration of work can be seen in the following table:

Table 4 The Probability of The Desired Duration of Work

Duration	Probability
158	10,56%
160	50%
161	73,4 %
162	89,43%
163	96,96%
164	99,37%

4. CONCLUSION

Based on the results of data processing and the discussion described above, it can be concluded that the network form for the Lettu Imam Building development project lies in the activity Preliminary Work – Concrete Work – Soil Work – Concrete

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Work – Concrete Work – Masonry Brick and Plaster Work – Wall and Floor Covering Work – Frame and Accessories Work – Roof Work – Ceiling Work – Painting Work – Mechanical and Electrical Work – Sanitation Work – Connection Work (Critical Path). For the optimal time duration for the Lettu Imam Building construction project from the results of research analysis using the PERT method obtained data that to obtain a project completion probability of 89,43% - 99,37%, the required duration of project implementation is 162 - 164 days.

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