The Analysis of Rescheduling the Savanna Sumatera Bridge Project Using the Pert Method

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ABSTRACT

Project schedules are generally created manually, which may lead to delays during the implementation on-site. It is due to the non-inclusion of the uncertainty factor in planning the project schedule. Delays in accomplishing one activity will result in delays in the next one. This study was intended to conduct rescheduling process to minimize the delay in the implementation of the Savanna Sumatera Bridge Project. The study applied PERT method in the rescheduling exercise by using three times conjectures on each project work item, which are: optimistic duration, most likely duration, and pessimistic duration. The results showed that the project was completed in 162 working days with a probability of completion of 99.9%, 34 days faster than the target project duration of 196 working days.

Keywords: most likely duration; optimistic duration; pessimistic duration; pert method; rescheduling.

INTRODUCTION

Construction projects commonly apply the concept of project management. The success factors of a construction project are cost, quality, and time. To achieve an optimal result within the timeframe, a project needs to have a good planning and scheduling management.

In principle, the scheduling of a project has been estimated with a definite duration, but there are several factors that cause the duration of each work cannot be determined with certainty. According to Pratama Yudha (2020), to achieve the objectives of a project, the contractor, developer, and owner are required to have an implementation schedule or timetable that can simultaneously control the implementation of each project. According to Saputra Niko et al. (2021), the success or failure of project implementation is often due to the poor planning of project activities and ineffective control, leading to inefficient project activities that will results in delays, decreased quality of work, and increased implementation costs.

Furthermore, according to Kartika Ni Kadek et al. (2023), the methods often used for the duration of work on network planning, are Critical Path Method (CPM) and Precedence Diagram Method (PDM) which are still deterministic. However, in practice, deterministic scheduling methods are not always in line with the initial planning because each project will not necessarily have the same characteristics as other projects. Therefore, one option to consider uncertainty in the duration of a project is to analyze the scheduling with probabilistic methods by using the PERT method.

The PERT method can accelerate project delivery and identify the probability that the project can be completed on time, thus underlying the idea of conducting a rescheduling analysis of the Savanna Sumatera Bridge project located on Jl. Jamin Ginting, Sugau, Kecamatan Pancur Batu, Deli Serdang Regency, North Sumatra 20353 with the period of implementation starting from January 15th, 2024 to August 11th, 2024.

RESEARCH METHODS

Location of the Study and Existing Conditions

This study is located in Savanna Sumatera Housing Jl. Jamin Ginting, Sugau, Kec. Pancur Batu, Deli Sedang Regency, North Sumatra 20353 where bridge construction will be carried out. The existing condition shows that the construction is at the bore pile foundation casting stage and has only reached 14.59% progress as shown in Figure 1 below.

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Figure 1. Current Condition of Study Sites

Data Collection

During this data collection stage, 2 (two) types of data were collected as follows:

a. Primary Data

The primary data was obtained by conducting direct observation and interviewing the relevant parties, the contractors. The requested data are 3 alleged time durations, which are optimistic duration (a), pessimistic duration (b), and most likely duration (m) for all of the project activity items of 3 informants including 1 project manager and 2 site engineers.

Table 1. Interview Data on Duration (a), (b), and (m)

No	Work Description	Duration (Day)			Duration (Day)			Duration (Day)		
		a	m	b	a	m	b	a	m	b
I	**Preparatory work**									
1	Construction Site Cleaning	7	14	17	7	14	16	7	14	17
2	Measurement/bowplank	5	7	10	5	6	9	5	6	10
3	Mobilization & demobilization	55	60	63	56	60	63	56	58	61
4	Procurement of electricity and water	150	155	160	148	156	160	147	156	160
5	Kit and warehouse director	150	155	160	148	156	160	147	156	160
6	Security	150	155	160	148	156	160	147	156	160
II	**Bridge Abutment**									
1	Bore pile diameter 40 cm	15	29	35	15	27	35	15	29	35
2	Concrete structure fc' 10 Mpa	4	7	9	5	7	9	4	7	9
3	Concrete structure fc' 20 Mpa	20	25	30	20	26	31	20	25	30
4	Reinforcement	25	28	31	25	29	35	25	28	31
III	**Precast Segmental Box Girder**									
1	PC-I Girder L=30,80 m; H=1,60 m; ctc=1.90 m	35	40	47	35	38	45	35	38	47
2	Peripheral diaphragm	8	10	12	7	10	12	6	8	12
3	Center diaphragm	8	10	12	8	10	12	8	10	12
4	precast plate t = 7cm	4	6	7	3	5	7	3	5	7
5	elastomeric bearing pad 400x400x52	2	5	7	3	5	7	2	5	7

No	Work Description	Duration (Day)			Duration (Day)			Duration (Day)		
		a	m	b	a	m	b	a	m	b
6	Fixed anchor	2	4	5	2	4	5	2	4	5
7	Move anchor	2	4	5	2	4	5	2	4	5
IV	**Bridge floor slab + Stepping plate**									
1	Concrete Fc' 30 Mpa	1	2	3	1	2	3	1	2	3
2	Reinforcement	21	28	35	21	28	35	21	28	35
3	asphaltic plug joint type E, t = 400 mm	2	5	7	2	3	4	2	3	5
4	asphaltic plug joint type F, t = 300 mm	2	5	7	2	3	4	2	3	5
V	**Parapet**									
1	Concrete Fc' 30 Mpa	4	6	8	4	5	7	4	5	7
2	Reinforcement	3	4	5	2	4	5	2	4	5
VI	**Drainage**									
1	deck drain	3	5	7	3	5	7	3	5	7
2	10-inch pipe	3	5	7	3	5	7	3	5	7
VII	**Additional Bridge Oprit**									
1	Reduced structure excavation	3	5	7	3	5	7	3	5	7

b. Secondary Data

Secondary data is the supporting data in the study. Secondary data was obtained from the contractor. As for the data obtained are:

1. Cost Budget Plan (RAB)
   The cost budget (RAB) for this project is Rp5,639,932,423.
2. Time schedule
   In terms of the SPK, this project requires 196 working days to complete the work on the whole project within the timeframe planned for the implementation of a construction. Time schedule can serve as a benchmark for achieving the targeted implementation time of a project. The time schedule for the Savanna Sumatera Bridge Project can be seen in Table Figure 2.

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TIME SCHEDULE THE SAVANNA SUMATERA BRIDGE PROJECT

No	Work Description	Unit	volume	Unit Price (Rp.)	Total Price (Rp.)	(%)	IMPLEMENTATION PERIOD (196 WORKING DAYS/210 CALENDAR DAYS)																													
							M1 (January)		M2 (February)					M3 (March)					M4 (April)				M5 (May)				M6 (June)				M7 (July)				M8 (August)	
							W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30
I	PREPARATORY WORK																																			
1	Construction Site Cleaning	Ls	1.00	7,250,000	7,250,000	0.13	0.06	0.06																												
2	Measurement/bowplank	Ls	1.00	17,000,000	17,000,000	0.30			0.10	0.10	0.10																									
3	Mobilization & demobilization	Ls	1.00	88,800,000	88,800,000	1.57			0.13	0.13	0.16	0.16	0.16	0.16	0.16	0.16	0.35																			
4	Procurement of electricity and water	Ls	1.00	49,550,000	49,550,000	0.88		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03			0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
5	Kit and warehouse director	Ls	1.00	35,500,000	35,500,000	0.63		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02			0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6	Security	Ls	1.00	59,500,000	59,500,000	1.05		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04			0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
					257,600,000	4.57																														
II	Bridge Abutment																																			
1	Bore pile diameter 40 cm	m'	280.00	3,954,664	1,107,305,920	19.63								3.93	3.93	3.93	3.93	3.93																		
2	Concrete structure fc' 10 Mpa	m3	6.32	1,758,746	11,111,757	0.20												0.20																		
3	Concrete structure fc' 20 Mpa	m3	215.73	2,637,527	568,993,700	10.09																3.36	3.36	3.36												
4	Reinforcement	Kg	25,061.27	16,409	411,230,379	7.29												2.36			2.36	1.5	1.07													
					2,098,641,756	37.21																														
III	Precast Segmental Box Girder																		IDUL FITRI HOLIDAY																	
1	PC-I Girder L=30,80 m; H=1,60 m; ctc=1.90 m	set	6.00	362,698,715	2,176,192,290	38.59																		3.89	6.49	6.49	7.79	7.79	6.14							
2	Peripheral diaphragm	bh	8.00	2,160,000	17,280,000	0.31																					0.31									
3	Center diaphragm	bh	12.00	2,160,000	25,920,000	0.46																					0.46									
4	precast plate t = 7 cm	bh	64.00	480,000	30,720,000	0.54																								0.54						
5	elastomeric bearing pad 400x400x52	bh	12.00	3,120,000	37,440,000	0.66																								0.66						
6	Fixed anchor	bh	12.00	600,000	7,200,000	0.13																									0.13					
7	Move anchor	bh	8.00	600,000	4,800,000	0.09																									0.09					
					2,299,552,290	40.77																														
IV	Bridge floor slab + Stepping plate																																			
1	Concrete Fc' 30 Mpa	m3	102.40	2,637,527	270,082,765	4.79																											1.50	3.29		
2	Reinforcement	Kg	25,783.74	16,409	423,085,390	7.50																								1.8	2.4	2.4	0.90			
3	asphaltic plug joint type E, t = 400 mm	m'	11.50	3,683,345	42,358,468	0.75																												0.75		
4	asphaltic plug joint type F, t = 300 mm	m'	11.50	3,683,345	42,358,468	0.75																												0.75		
					777,885,089	13.79																														
V	Parapet																																			
1	Concrete Fc' 30 Mpa	m3	31.98	2,637,527	84,348,113	1.50																														1.50
2	Reinforcement	Kg	3,255.57	29,409	95,743,058	1.70																													1.70	
					180,091,172	3.19																														
VI	Drainage																																			
1	deck drain	set	10.00	1,440,000	14,400,000	0.26																													0.255	
2	10-inch pipe	m'	44.00	165,389	7,277,116	0.13																													0.129	
					21,677,116	0.38																														
VII	Additional Bridge Oprit																																			
1	Reduced structure excavation	m3	69.00	65,000	4,485,000	0.08					0.08																									
					4,485,000	0.08																														
	TOTAL					100.00																														
	RECAPITULATION																																			
	TOTAL				5,639,932,423																															
	ROUNDING				5,640,000,000																															
	PLAN PROGRESS						0.06	0.16	0.33	0.33	0.43	0.25	0.25	4.18	4.18	4.18	4.38	6.58	-	-	2.45	4.96	4.53	7.35	6.58	6.58	8.65	7.88	6.23	3.10	2.71	2.49	2.50	4.89	2.18	1.59
	CUMULATIVE PLAN PROGRESS						0.06	0.22	0.55	0.87	1.31	1.56	1.82	6.00	10.18	14.36	18.74	25.32	25.32	25.32	27.77	32.73	37.26	44.61	51.19	57.78	66.43	74.31	80.54	83.65	86.36	88.85	91.35	96.23	98.41	100.00
	REALIZATION PROGRESS						-	0.11	0.18	0.54	2.49	3.15	-	-	0.75	4.21	3.16	9.16																		
	CUMULATIVE REALIZATION PROGRESS						-	0.11	0.29	0.83	3.32	6.47	6.47	6.47	7.22	11.43	14.59	23.75	23.75																	
	DEVIATION						(0.06)	(0.11)	(0.26)	(0.04)	2.01	4.91	4.65	0.47	(2.96)	(2.93)	(4.15)	(1.57)	(1.57)																	

Figure 2. Time Schedule

Stages of Study

The stages of study are depicted in the flowchart in Figure below.

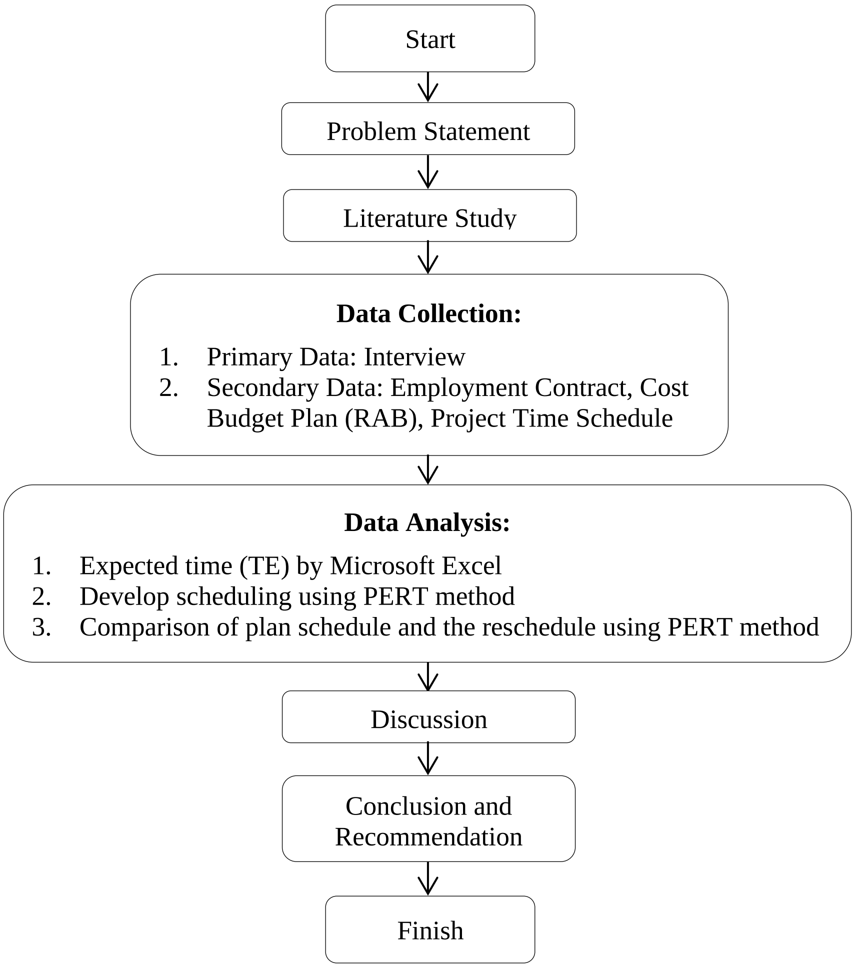

Figure 3. Stages of Study Flowchart

Data Analysis

The data obtained from the project is analyzed using the PERT scheduling method as well as any activity included in critical activities and the impact on project implementation with the assistance of Microsoft Excel 2016 and Microsoft Project 2010 so that expected time (TE) can be analyzed and network planning can be made to determine the project implementation time.

a. The average of the 3 alleged time durations for the optimistic (a), most likely (m), and pessimistic (b) from the three interviewees i.e.: 1 project manager and 2 site engineers.
b. Calculate the average (expected) duration of each activity by the formula:
   $\boldsymbol{TE = \frac{a+4m+b}{6}}$
   Description:
   TE = Expected time
   a = Optimistic time
   b = Pessimistic time
   m = Normal time
c. Calculate the activity standard deviation:
   The calculation of the standard deviation of each activity is required to calculate the variance of the activity. The calculation is based on the following formula
   S = (b – a) / 6

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Description:
b = Pessimistic duration
a = Optimistic duration

d. Calculate the variance
The square of standard deviation is variance. The calculation can be done by following the formula, $\mathbf{V = S^2}$.

e. Scheduling Analysis in Microsoft Project 2010
According to (Wahyudin et al., 2021) Scheduling analysis with Microsoft Project 2010 Software is needed to determine task completion time, critical path, and task network. The data obtained from the previous calculation is in the form of sequence of activities, optimistic duration, pessimistic duration, most likely duration that is analyzed using the PERT method to get the average duration of each job (TE). The process is as follows:
- Before proceeding to enter the activity data, first, set the start time of the project in the Project Information.
- Then, input the project activity data by typing the sequence activities on the task name column and the activity time on the duration column. Start and finish column will be automatically filled.
- To create the task network, add the dependency relationship "before" in Predecessors. In this column, the activity relationship is simply entering the work ID number, for instance, the bowplank installation with number 3, the excavation pile cap with number 5, and so on. The Bar Chart and its interrelationship will be displayed automatically on the right sheet of the Gantt chart.
- After the task network completed, the critical path of the entire task is displayed.
- Change the view. Microsoft Project 2010 consists of several views, i.e. Calendar, Network Diagram, Task Usage, Resources Graph and others. Switching views can be made by selecting the *View* menu.

f. Project Probability Analysis
Before calculating the Z, first, calculate the project variance and standard deviation. The formula is as follows:
Project Variance = $\sum$ (activities variance on the critical path)
Project Standard Deviation = $\sqrt{\text{Critical Variance}}$
After finding the project standard deviation, then calculate the Z. In the PERT method, the relationship between expected time (TE) and the target T(d) is expressed by Z and formulated as follows:

$$\mathbf{Z} = \frac{\mathbf{T(d)} - \boldsymbol{Te}}{\mathbf{s}}$$

After obtaining the Z, then look for the probability number using the normal Z distribution table.

Results and Discussion

Based on the results of task network analysis using Microsoft Project 2010, it is obtained that critical path, the relationship between total expected duration TE and target duration TD is Z. Therefore, to find out the probability of the project being completed on the desired target, with the TE from Microsoft Project 2010 is 162 days. The project target TD on the project's Existing Time Schedule is 196 days.
The dependency relationship between tasks items can be seen on the table below.

Table 2. Dependency Relationship between Task Items

No.	Task Name	Duration	Predecessors	Constraint
1	**Savanna sumatera bridge project**	**162 days**		
2	**Preparatory work**	**162 days**		
3	Construction Site Cleaning	13 days		
4	Measurement/bowplank	7 days	Task No.3	FS=0

No.	Task Name	Duration	Predecessors	Constraint
5	Mobilization & demobilization	59 days	Task No.3	FS=0
6	Procurement of Electricity & Water	154 days	Task No.3	SS+7 days
7	Kit & Warehouse Director	154 days	Task No. 6	SS=0
8	Security	154 days	Task No. 6	SS=0
9	**Bridge abutment**	**59 days**		
10	Bore pile diameter 40 cm	27 days	Task No. 4	FS+14 days
11	Concrete structure fc' 10 Mpa	7 days	Task No. 10	SS+20 days
12	Concrete structure fc' 20 Mpa	25 days	Task No. 13	SS+14 days
13	Reinforcement	28 days	Task No. 11	SS-0
14	**Precast Segmental Box Girder**	**48 days**		
15	PC-I Girder L=30,80 m; H=1,60 m; ctc=1.90 m	39 days	Task No. 13	FS=0
16	Peripheral diaphragm	9 days	Task No. 15	SS+21 days
17	Center diaphragm	10 days	Task No. 16	SS=0
18	Precast plate t = 7 cm	5 days	Task No. 15	FS=0
19	Elastomeric bearing pad 400x400x52	5 days	Task No. 18	SS=0
20	Fixed anchor	4 days	Task No. 19	FS=0
21	Move anchor	4 days	Task No. 20	SS=0
22	**Bridge floor slab + Stepping plate**	**32 days**		
23	Concrete, Fc' 30 Mpa	2 days	Task No. 24	FS=0
24	Reinforcement	28 days	Task No. 15	FS=0
25	Asphaltic plug joint type E, t = 400 mm	4 days	Task No. 24	FS=0
26	Asphaltic plug joint type F, t = 300 mm	4 days	Task No. 24	FS=0
27	**Parapet**	**9 days**		
28	Concrete, Fc' 30 Mpa	5 days	Task No. 29	FS=0
29	Reinforcement	4 days	Task No. 26	FS=0
30	**Drainage**	**5 days**		
31	Deck drain	5 days	Task No. 29	SS=0
32	10-inch pipe	5 days	Task No. 31	SS=0
33	**Additional Bridge Oprit**	**5 days**		
34	Reduced Structure Excavation	5 days	Task No. 4	SS+2 days

Table 3. Below is the critical path of the Savanna Sumatera Bridge Project:

No.	Task Description
A	**Preparatory work**
1	Construction Site Cleaning
2	Measurement/Bowplank
B	**Bridge Abutment**
1	Bore Pile Diameter 40 Cm
2	Concrete Structure Fc' 10 Mpa
3	Reinforcement
C	**Precast Segmental Box Girder**

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No.	Task Description
1	PC-I Girder L=30,80 m; H=1,60 m; ctc=1.90 m
D	**Bridge floor slab + Stepping plate**
1	Reinforcement
2	Asphaltic plug joint type F, t = 300 mm
E	**Parapet**
1	Concrete, Fc' 30 Mpa
2	Reinforcement

Furthermore, the critical path can be used to determine the probability using the following calculation.
After finding out the estimation of optimistic duration (a), pessimistic duration (b), and most likely duration (m), the next step in preparing probabilistic scheduling is to formulate the relationship between these three numbers into the expected duration (Te) to get the probability of project completion.
TD = 196 days
TE = 162 days
After the expected duration (Time Expected) is obtained, then, calculate the project variance by summing the activities variance on the critical path as in the formula below:
Project Variance
Project Variance = ∑ (activities variance on the critical path)
Here is the Project Variance calculation
= ∑ (Activities Variance on the Critical Path (Construction Site Cleaning +
= Measurement/Bowplank + Bore Pile dia. 40 cm of Bridge Abutment + Concrete
= Structure fc' 10 Mpa of Bridge Abutment + Reinforcement of Bridge Abutment +
= PC- I Girder L=30,80 m; H=1,60 m; ctc=1.90 m of Precast Segmental Box Girder +
= Reinforcement of Bridge floor slab & Stepping plate of Precast Segmental Box Girder +
= Asphaltic plug joint type F, t = 300 mm of Precast Segmental Box Girder +
= Concrete, Fc' 30 Mpa of Parapet + Reinforcement of Parapet))
= ∑ **(2,6+0,6+11,1+0,6+1,5+3,6+5,4+0,3+0,3+0,2)**
= **26,24**

After the Project Variance is obtained, calculate the Project Standard Deviation by rooting the Activities Variance on the Critical Path as in the formula below:
Project Standard Deviation
Project Standard Deviation $= \sqrt{\textbf{Critical Variance}}$
Here is the Project Standard Deviation calculation:
$= \sqrt{\mathbf{26,24}}$
= **5,12**
After obtaining the Project Standard Deviation, calculate the Z with the following formula:
$$\mathbf{Z} = \frac{\mathbf{TD-TE}}{\mathbf{S}}$$
Here is the Z calculation:
$$= \frac{\mathbf{196-162}}{\mathbf{5,12}} = \mathbf{6,64}$$
Based on the above calculation, **Z = 6,64**, therefore, based on the Z table, probability of the project can be done is **99,9%**. From rescheduling using PERT method, the project completion duration is 162 working days, 34 days faster than the existing project schedule that is in 196 working days. The recapitulation of TE, Z, and probability calculations is shown in the table below.

Table 4. The Recapitulation of TE, Z, and Probability Calculation

No	Task Name	Duration (Day)			TE	Rounding	Standard Deviation Activity	Activity Variance
		a	m	b				

I	**Preparatory work**							
1	Construction Site Cleaning	7.0	14.0	16.7	13.3	13.0	1.6	2.6
2	Measurement/bowplank	5.0	6.3	9.7	6.7	7.0	0.8	0.6
3	Mobilization & demobilization	55.7	59.3	62.3	59.2	59.0	1.1	1.2
4	Procurement of Electricity & Water	148.3	155.7	160.0	155.2	155.0	1.9	3.8
5	Kit & Warehouse Director	148.3	155.7	160.0	155.2	155.0	1.9	3.8
6	Security	148.3	155.7	160.0	155.2	155.0	1.9	3.8
II	**Bridge Abutment**							
1	Bore pile diameter 40 cm	15.0	28.3	35.0	27.2	27.0	3.3	11.1
2	Concrete structure fc' 10 Mpa	4.3	7.0	9.0	6.9	7.0	0.8	0.6
3	Concrete structure fc' 20 Mpa	20.0	25.3	30.3	25.3	25.0	1.7	3.0
4	Reinforcement	25.0	28.3	32.3	28.4	28.0	1.2	1.5
III	**Precast Segmental Box Girder**							
1	PC-I Girder L=30,80 m; H=1,60 m; ctc=1.90 m	35.0	38.7	46.3	39.3	39.0	1.9	3.6
2	Peripheral diaphragm	7.0	9.3	12.0	9.4	9.0	0.8	0.7
3	Center diaphragm	8.0	10.0	12.0	10.0	10.0	0.7	0.4
4	Precast plate t = 7 cm	3.3	5.3	7.0	5.3	5.0	0.6	0.4
5	Elastomeric bearing pad 400x400x52	2.3	5.0	7.0	4.9	5.0	0.8	0.6
6	Fixed anchor	2.0	4.0	5.0	3.8	4.0	0.5	0.3
7	Move anchor	2.0	4.0	5.0	3.8	4.0	0.5	0.3
IV	**Bridge floor slab + Stepping plate**							
1	Concrete , Fc' 30 Mpa	1.0	2.0	3.0	2.0	2.0	0.3	0.1
2	Reinforcement	21.0	28.0	35.0	28.0	28.0	2.3	5.4
3	asphaltic plug joint type E, t = 400 mm	2.0	3.7	5.3	3.7	4.0	0.6	0.3
4	asphaltic plug joint type F, t = 300 mm	2.0	3.7	5.3	3.7	4.0	0.6	0.3
V	**Parapet**							
1	Concrete , Fc' 30 Mpa	4.0	5.3	7.3	5.4	6.0	0.6	0.3
2	Reinforcement	2.3	4.0	5.0	3.9	4.0	0.4	0.2
VI	**Drainage**							
1	deck drain	3.0	5.0	7.0	5.0	5.0	0.7	0.4
2	10 inch pipe	3.0	5.0	7.0	5.0	5.0	0.7	0.4
VII	**Additional Bridge Oprit**							
1	Reduced Structure Excavation	3.0	5.0	7.0	5.0	5.0	0.7	0.4
	Total					**162**	**13,50**	**26,24**
	Z	**6,64**						
	Probability	**99,9%**						

CONCLUSION

Based on the results of the analysis, project completion duration by scheduling using the PERT method is 162 working days. The rescheduling by using the PERT method results in a faster duration compared to the existing schedule of Savanna Sumatera Bridge Project which is 34 days faster than the target duration that is in 196 days, with the probability of the project can be completed at 99,9%.

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