JISO: Journal Of Industrial And Systems Optimization
Volume 7, Nomor 1, Juni 2024, 31-38

ISSN 2622-898X online
ISSN 2622-8971 print

SCHEDULING EVALUATION OF CONSTRUCTION PROJECT USING FUZZY LOGIC APPLICATION FOR SCHEDULING (FLASH) METHOD

Devina Bianca Putri Rahadyan Hasugian[1], **Aditya Maharani**[2], **Farizi Rachman**[3*]
*E-mail Korespondensi: farizirachman@ppns.ac.id
[1,3]Engineering Design and Manufacture Study Program, Department of Mechanical Engineering
Politeknik Perkapalan Negeri Surabaya, Indonesia
[2]Maritime Business Management Study Program, Department of Shipbuilding Engineering
Politeknik Perkapalan Negeri Surabaya, Indonesia

ABSTRAK

Dalam pengerjaan suatu proyek diperlukan perencanaan proyek berupa penjadwalan proyek. PT Ometraco Arya Samanta merupakan perusahaan konstruksi baja. Perusahaan ini memanfaatkan penjadwalan berdasarkan tonase proyek. Metode tersebut dirasa belum optimal, sebab dalam pelaksanaannya sering kali terjadi ketidaksesuaian waktu penyelesaian proyek antara rencana dengan aktualnya. Untuk mendapatkan penjadwalan yang optimal, diperlukan metode yang tepat. Proyek konstruksi merupakan proyek yang kompleks dan memiliki durasi penyelesaian yang bersifat tidak pasti. Project Evaluation and Review Technique (PERT) dan Fuzzy Logic Application for Scheduling (FLASH) dapat digunakan untuk proyek yang memiliki ketidakpastian waktu dan menekankan pada estimasi waktu daripada biaya. PERT dan FLASH menggunakan tiga estimasi waktu yang kemudian didapatkan persentase kemungkinan terselesaikannya proyek. Namun, PERT hanya memperhitungkan waktu penyelesaian proyek berdasarkan lintasan kritis, sedangkan FLASH dapat mempertimbangkan waktu proyek dari keseluruhan kegiatan proyek. Sehingga, metode yang digunakan di dalam artikel ini adalah FLASH. Hasil analisis dari penelitian ini didapatkan selang waktu penyelesaian proyek yaitu waktu paling cepat 106 hari, waktu paling lama 237 hari, dan waktu paling mungkin sebesar 169 hari. Dengan menggunakan waktu target 179 hari, didapatkan probabilitas sebesar 85,29% dari rentang waktu 169 hari hingga 237 hari.

Keywords: proyek konstruksi, logika fuzzy, penjadwalan proyek, tiga estimasi waktu

ABSTRACT

For the running of a project, it is necessity to have project planning such as project schedule. PT Ometraco Arya Samanta is a company that engaged in steel structure. This company implement schedule planning based on tonnage. This method is considered suboptimal, since in its implementation has discrepancy of completion time between the schedule plan and the actual. To get an optimal schedule, it needs appropriate method. Construction project is a complex project and has uncertainty completion time. Project Evaluation and Review Technique (PERT) and Fuzzy Logic Application for Scheduling (FLASH) could be used for projects with uncertain completion time and more emphasis on time estimation than cost. PERT and FLASH are using three estimation time, then obtained probability percentage of completion time. Nevertheless, PERT is only consider the completion time by the critical path, while FLASH is able to determine project time by the entire project activities. Thereby, the methods used in this article is FLASH. The analysis results of this case study as follows: the interval completion time with FLASH in the amount of 106 days for optimistic time, 237 days for pessimistic time, and 169 days for most likely time. By the duration target of 179 days, it is obtained 85,29%.

Keywords: *construction project, fuzzy logic, project scheduling, three estimation time*

INTRODUCTION

PT Ometraco Arya Samanta is a company engaged in steel construction and civil specialization in Surabaya. Projects performed by this company are fabrication and installation of steel construction. This company conducts variative projects, and each project has its uniqueness. The series of activities for a project is run by one to produce a unique product. Project duration depends on the contract agreement, yet project scheduling in PT Ometraco Arya Samanta commonly has discrepancies with the initial plan.

PT Ometraco Arya Samanta implements scheduling based on project load. It is considered inefficient and far from actual, thereby often causing delays in the implementation. In every project, it has complex relations between each activity. Thus, it is hard to know the activity time (Trisian et al., 2022). Several factors are causing the discrepancy between the actual and the initial plan: shop drawings require improvements, many projects pile up, and inefficient working hours.

One of the delayed projects is the warehouse and facility installation project owned by PT Sariguna Primatirta. The work period for this project is 150 days. It starts from August 15th, 2022, until January 15th, 2023. However, this project begins on September 12th, 2022. On January 2023, this project realization is still in the delivery process. It could affect delays in project installation. Thus, the project can not be finished on time.

It shows that project scheduling in this company is not lead to optimal turnaround time. Scheduling is considered inappropriate for complex projects and has a probabilistic turnaround time. There are several common scheduling methods used for project management, namely Critical Path Method (CPM), Precedence Diagram method (PDM), Project Evaluation and Review Technique (PERT), and so on. CPM and PDM are scheduling methods that use network planning same goes for PERT. This method emphasizes time estimation rather than cost and is appropriate for probabilistic projects (Santosa, 2009).

According to Trisiana et al. (2022), the PERT method is used to analyze the probability of the whole project duration in its critical path. However, there are unrealized activities. Due to this weakness of PERT, thus it requires a method that has the similarity yet could overcome the weakness, namely Fuzzy Logic Application for Scheduling (FLASH). FLASH can express uncertainty in analyzing completion time by activity duration stated in the Triangular Fuzzy Number (TFN) (Vizkia, 2014) and the probability of computed activity duration.

MATERIALS AND METHOD

This section will discuss about the main literature review supporting this article, as well as the research methods.

Work Breakdown Structure

According to Project Management Institute (1996) in Golany et al (2001), Work Breakdown Structure (WBS) is a classification of project elements that are deliverable-oriented and control and define the total scope of the project. Every level down can represent a detailed definition of project components. Project components could be products or services. WBS is designed to help to break down the project into pieces that can be managed, estimated, and controlled effectively (Devi et al, 2012).

WBS is created before identifying dependency relationships and before estimating activity duration. By utilizing a list of works in WBS it would be easy to estimate the required duration to finish each activity. The list of works for each project is not always the same as others, but it has several identical activities.

Network Planning

Network planning is a way to describe graphically of require activities to reach project goals (Widiasanti et al, 2013). It is also a comprehensive management tool which probably for planning and controlling projects (Rani, 2016). According to Santosa (2009), there are two approaches to illustrating a network planning diagram; Activity on Node (AON) as follows the Figure 1, and Activity on Arrow (AOA) as follows the Figure 2.

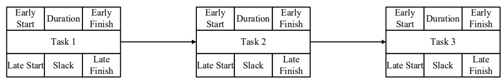

Figure 1. Ilustration of Acitivty on Node

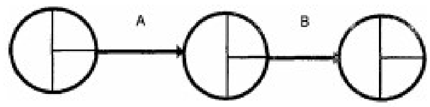

Figure 2. Ilustration of Acitivty on Arrow

A series of activities and critical paths are shown in network planning. The critical path could be determined by using Critical Path Method (CPM). CPM's computation consists of forward and backward passes. Forward pass is used to know the early start and finish of the activity. The activity under review is denoted as j, and the predecessor activity is denoted as i. In this computation is used the following equation.

$$EF_{(j)} = ES_{(j)} + t_{(j)} \; or \; EF_{(i)} + t_{(j)} \tag{1}$$

Backward pass is used to know the latest start and finish of the activity. It has a different notation with forward pass, the i notation is for activity under review and the j notation is for successor activity. The equation of backward pass is as the following:

$$LS_{(i)} = LF_{(i)} - t_{(i)} \; or \; LS_{(j)} - t_{(i)} \tag{2}$$

Slack is a grace time to start or finish a work. Determine the Slack aims to know which activities that include the critical path. Slack can be determined by the following equation:

$$S_{(i,j)} = LF_{(i,j)} - EF_{(i,j)} \; or \; LS_{(i,j)} - ES_{(i,j)} \tag{3}$$

Fuzzy logic is a method that is used to manage uncertainty. The concept of a fuzzy set is mapping the input domain into the output domain. The fuzzy set also has a lot of output values, also known as membership values which have a value between 0 to 1. In linguistics, it defines as little, fair, and many.

In its application for scheduling, this method is using three-time estimation. The duration is stated in three different values, namely lower limit, most likely, and upper limit. In this case, the membership function used is Triangular Fuzzy Number. The duration is notated as the following equation:

$$\tilde{t}_{(i,j)} = (a, m, b) \quad (4)$$

FLASH is helped by the decision maker's risk index (λ) and the ranking value of the activities that have more than one predecessor or successor. It aims to determine the activity duration. The λ can be obtained by the following equation (Elizabeth et al, 2013):

$$\lambda = \left[\sum_{\substack{i \\ A_{ij} \in SA}} \sum_{j} \frac{b_{ij} - a_{ij}}{(m_{ij} - a_{ij}) + (b_{ij} - m_{ij})} \right] / t \quad (5)$$

Where SA is notation of the set of all activities and t is the number of activities. And the ranking value can be obtaines as follows:

$$R(\tilde{L}_i) = \lambda \left[\frac{b_i - X_1}{X_2 - X_1 + b_i - m_i} \right] + (1 - \lambda) \left[1 - \frac{X_2 - a_i}{X_2 - X_1 + m_i - a_i} \right] \quad (6)$$

Where X_1 : min (a_1, a_2, ..., a_n) and X_2 : max (b_1, b_2, ..., b_n).

FLASH also has two approaches, namely forward pass and backward pass. This computation is helped by the decision maker's risk index (λ) and the ranking value mentioned above. It has the same equation as CPM.

The critical path of the activities must be the same with CPM, yet to ensure the result it can be conducted by determining the slack of FLASH as follows:

$$\tilde{S}_{(i,j)} = \tilde{L}F_{(i,j)} - \tilde{L}S_{(i,j)} - \tilde{t}e_{(i,j)} \quad (7)$$

Research Method

This research was conducted in PT Ometraco Arya Samanta. The observation aims to get the general specification about the system of the project will be researched and know the encountered problems. In this research also supported by some literatures study. It aims to deep dive into the materials obtained in several relevant books or journals, thus can ensure that the research has not been conducted yet and developed by previous research. After that, determine the research problem by find some scheduling issues that went out of the plan. Then, it starts to collecting the required data, it includes project information, schedule plan, series of activities, and duration of each activity. A series of activities and duration is conducted by interviewing several workers.

The first stage of the data processing is create the work breakdown structure of the project. Then, estimate the duration and determine the dependency relationship in each activity. The next stage is compute the total completion time by CPM to make it as a target time of the project. And then the last stage is calculate the project time using FLASH, it consists of three steps, namely: estimate the duration by using three variabels of time, calculate the forward and the backward pass, and determine the probability of time. The entire stages of this research is shown in Figure 3.

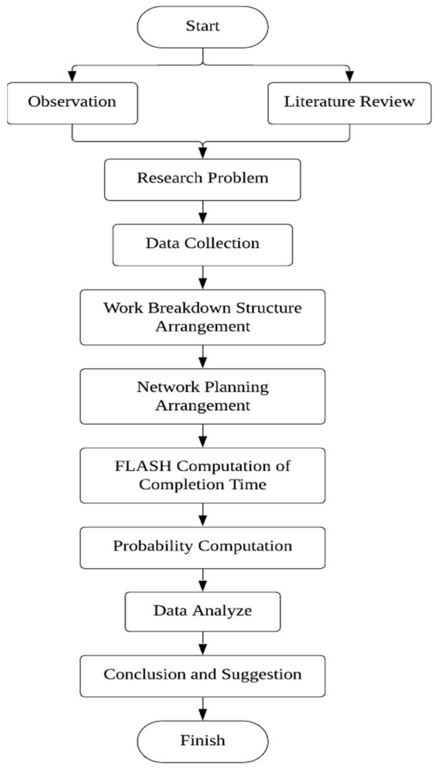

Figure 3. Research Method

RESULT AND DISCUSSION

Activity Classification

In schedule planning is required network planning to know the activities, the duration, and the dependencies. The activity classification can be divided into several parts by using Work Breakdown Structure. WBS has functioned as a project organizational diagram to break down the project into activities. the following is the WBS of the entire activities in the warehouse and facility project:

a. PO Award
b. Engineering, this activity is consists of surat perintah kerja and shop drawing.
c. Procurement, this activity is consists of PRP and Material Received.

d. Fabrication, this activity is consists of marking, cutting, drilling, fitting, welding and finishing.
e. Sand blasting
f. Painting, this activity is consists of primer and finish coat.
g. QC Check
h. Packing
i. Delivery
j. Installation, this activity is divided into 2 parts, i.e. warehouse and support building installation.

Activity Duration and Predecessor

Network planning is a method that shows the sequence and the duration of activities, it uses for estimating the total completion time. WBS can ease the arrangement of network planning to identify activities and also the dependencies relationship.

Table 1. Activity Duration and Predecessor

No	Activity	Duration (day)	Predecessor
A	**Purchase Order**	2	
B	**Engineering**		
1	Work Order	3	A
2	Shop Drawing	32	A
C	**Procurement**		
1	PRP	5	B1, B2
2	Material Received	28	C1
D	**Fabrication**		
1	Marking	2	C2
2	Cutting	4	D1
3	Drilling	2	D2
4	Fitting	2	D3
5	Welding	3	D4
6	Finishing	2	D5
E	**Sand Blasting**	2	D6
F	**Painting**		
1	Primer	2	E
2	Finish Coat	2	F1
G	**QC Check**	4	D6, F2
H	**Packing**	3	G
I	**Delivery**	2	H
J	**Installation**		
1	Warehouse		
	a. Preparation	3	B1
	b. Warehouse Foundation	6	J1a, C1
	c. Perimeter Soil Retaining Wall	6	J1b
	d. Ground	4	J1c
	e. Concrete Structure	13	J1d
	f. Steel Structure	45	I, J1e
	g. Arsitecture	3	J1f
	h. Electricity Installation	3	J1g
	i. Infrastucture	3	J1h
2	Support Building		
	a. Foundation	2	J1i
	b. Ground	2	J2a
	c. Concrete Structure	7	J2b
	d. Steel Structure	11	J2c
	e. Arsitecture	2	J2d
	f. Electricity Installation	2	J2e
	g. Plumbing	2	J2f

Network Planning

The next stage is identifying the critical path by determining forward and backward passes. Forward pass is used to gain the early start (ES) and the early finish (EF) of the activities. while backward pass is used to find out the latest start (LS) and the latest finish (LF).

Slack or total float is an allowed deadline for project delay without affecting the turnaround time. Activities can be called critical if the slack is equal to 0. It can be determined by the subtraction operation of EF by LF or ES by LS.

Table 2. Forward and Backward Pass

No	Activity	ES	EF	LS	LF
A	**Purchase Order**	0	2	0	2
B	**Engineering**				
1	Work Order	2	5	31	34
2	Shop Drawing	2	34	2	34
C	**Procurement**				
1	PRP	34	39	34	39
2	Material Received	39	67	39	67
D	**Fabrication**				
1	Marking	67	69	67	69
2	Cutting	69	73	69	73
3	Drilling	73	75	73	75
4	Fitting	75	77	75	77
5	Welding	77	80	77	80
6	Finishing	80	82	80	82
E	**Sand Blasting**	82	84	82	84
F	**Painting**				
1	Primer	84	86	84	86
2	Finish Coat	86	88	86	88
G	**QC Check**	88	92	88	92
H	**Packing**	92	95	92	95
I	**Delivery**	95	97	95	97
J	**Installation**				
1	Warehouse				
	a. Preparation	5	8	65	68
	b. Warehouse Foundation	39	45	68	74
	c. Perimeter Soil Retaining Wall	45	51	74	80
	d. Ground	51	55	80	84
	e. Concrete Structure	55	68	84	97
	f. Steel Structure	97	142	97	142
	g. Arsitecture	142	145	142	145
	h. Electricity Installation	145	148	145	148
	i. Infrastucture	148	151	148	151
2	Support Building				
	a. Foundation	151	153	151	153
	b. Ground	153	155	153	155
	c. Concrete Structure	155	162	155	162
	d. Steel Structure	162	173	162	173
	e. Arsitecture	173	175	173	175
	f. Electricity Installation	175	177	175	177
	g. Plumbing	177	179	177	179

 ISSN 2622-898X online
ISSN 2622-8971 print

Table 3. Slack of the Activity

No	Activity	Float	Desc
A	**Purchase Order**	0	Critical
B	**Engineering**		
1	Work Order	29	Uncritical
2	Shop Drawing	0	Critical
C	**Procurement**		
1	PRP	0	Critical
2	Material Received	0	Critical
D	**Fabrication**		
1	Marking	0	Critical
2	Cutting	0	Critical
3	Drilling	0	Critical
4	Fitting	0	Critical
5	Welding	0	Critical
6	Finishing	0	Critical
E	**Sand Blasting**	0	Critical
F	**Painting**		
1	Primer	0	Critical
2	Finish Coat	0	Critical
G	**QC Check**	0	Critical
H	**Packing**	0	Critical
I	**Delivery**	0	Critical
J	**Installation**		
1	Warehouse		
	a. Preparation	60	Uncritical
	b. Warehouse Foundation	29	Uncritical
	c. Perimeter Soil Retaining Wall	29	Uncritical
	d. Ground	29	Uncritical
	e. Concrete Structure	29	Uncritical
	f. Steel Structure	0	Critical
	g. Arsitecture	0	Critical
	h. Electricity Installation	0	Critical
	i. Infrastucture	0	Critical
2	Support Building		
	a. Foundation	0	Critical
	b. Ground	0	Critical
	c. Concrete Structure	0	Critical
	d. Steel Structure	0	Critical
	e. Arsitecture	0	Critical
	f. Electricity Installation	0	Critical
	g. Plumbing	0	Critical

Based on the slack computation, it is obtained the critical path of the project. The critical path is A-B2-C1-C2-D1-D2-D3-D4-D5-D6-E-F1-F2-G-H-I-J1f-J1g-J1h-J1i-J2a-J2b-J2c-J2d-J2e-J2f-J2g. So, the network planning can be described in Figure 4 below.

Activity Duration by FLASH

In this method, the duration of activities is stated in three parameters, i.e. optimistic time, pessimistic time, and most likely time. These parameters will be served in fuzzy number notation. Since there are three parameters of time, it will just one number possibly have a membership value of one, namely most likely time. The three estimation time as follows:

Table 4. Three Estimation Time

No	Activity	Duration (day)		
		a	m	b
A	**Purchase Order**	1	2	3
B	**Engineering**			
1	Work Order	2	3	5
2	Shop Drawing	14	21	30
C	**Procurement**			
1	PRP	3	5	7
2	Material Received	14	30	45
D	**Fabrication**			
1	Marking	1	2	3
2	Cutting	2	4	6
3	Drilling	1	2	3
4	Fitting	1	2	3
5	Welding	2	3	4
6	Finishing	1	2	3
E	**Sand Blasting**	1	2	3
F	**Painting**			
1	Primer	2	2	3
2	Finish Coat	1	2	3
G	**QC Check**	1	1	2
H	**Packing**	1	2	3
I	**Delivery**	2	2	3
J	**Installation**			
1	Warehouse			
	a. Preparation	2	3	4
	b. Warehouse Foundation	4	6	7
	c. Perimeter Soil Retaining Wall	4	6	7
	d. Ground	3	4	5
	e. Concrete Structure	10	13	15
	f. Steel Structure	30	45	60
	g. Arsitecture	2	3	4
	h. Electricity Installation	2	3	4
	i. Infrastucture	2	3	4
2	Support Building			
	a. Foundation	2	3	4
	b. Ground	2	3	4
	c. Concrete Structure	5	7	10
	d. Steel Structure	10	12	14
	e. Arsitecture	1	2	3
	f. Electricity Installation	1	2	3
	g. Plumbing	1	2	3

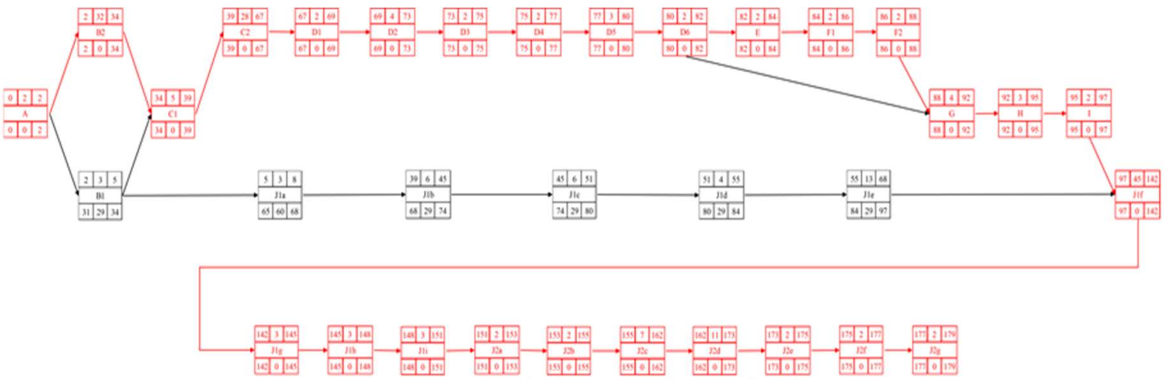

Figure 4. Network Planning with Critical Path

Forward and Backward Pass by FLASH

It has a similarity to the calculation of CPM. The earliest start in the first activity is defined as 0, so the early finish of the activity can be calculated by using the same equation as CPM.

In the activity that has more than one predecessor, it must be determined by the decision maker's risk index, such as equation 5, as follows:

$$\widetilde{EF}_{(C1)} = \max(\widetilde{EF}_{(B1)} + \tilde{t}_{(C1)}, \widetilde{EF}_{(B2)} + \tilde{t}_{(C1)})$$
$$= \max\{(3,5,8) + (3,5,7), (15,23,33) + (3,5,7)\}$$
$$= \max\{(6,10,15), (18,28,40)\}$$

$$\lambda = \left[\frac{m_A - a_A}{(m_A - a_A) + (b_A - m_A)} + \frac{m_{B1} - a_{B1}}{(m_{B1} - a_{B1}) + (b_{B1} - m_{B1})} + \cdots \frac{m_{J27} - a_{J27}}{(m_{J27} - a_{J27}) + (b_{J27} - m_{J27})}\right] \Big/ t$$

$$\lambda = \left[\frac{2-1}{(2-1)+(3-2)} + \frac{3-2}{(3-2)+(5-3)} + \cdots \frac{2-1}{(2-1)+(3-2)}\right] \Big/ 33$$

λ=0,4804

By λ=0,4804, so the ranking value for (6,10,15) and (18,28,40) with $X_1 = 6$ and $X_2 = 40$ can be calculated by using equation 6. Based on the ranking value, it is obtained $\widetilde{EF}_{(C1)} = (18,28,40)$.

Table 5. Forward Pass by FLASH

Activity Code	FES			FEF		
	a	m	b	a	m	b
A	0	0	0	1	2	3
B1	1	2	3	3	5	8
B2	1	2	3	15	23	33
C1	15	23	33	18	28	40
C2	18	28	40	32	58	85
D1	32	58	85	33	60	88
D2	33	60	88	35	64	94
D3	35	64	94	36	66	97
D4	36	66	97	37	68	100
D5	37	68	100	39	71	104
D6	39	71	104	40	73	107
E	40	73	107	41	75	110
F1	41	75	110	43	77	113
F2	43	77	113	44	79	116
G	44	79	116	45	80	118
H	45	80	118	46	82	121
I	46	82	121	48	84	124
J1a	3	5	8	5	8	12
J1b	18	28	40	22	34	47
J1c	22	34	47	26	40	54
J1d	26	40	54	29	44	59
J1e	29	44	59	39	57	74
J1f	48	84	124	78	129	184
J1g	78	129	184	80	132	188
J1h	80	132	188	82	135	192
J1i	82	135	192	84	138	196
J2a	84	138	196	86	141	200
J2b	86	141	200	88	144	204
J2c	88	144	204	93	151	214
J2d	93	151	214	103	163	228
J2e	103	163	228	104	165	231
J2f	104	165	231	105	167	234
J2g	105	167	234	106	169	237

Same as forward pass, in backward pass the activity that have more than one successors must be determine by decision maker's risk index, as follows:

$$\widetilde{LS}_{(C1)} = \min(\widetilde{LS}_{(C2)} - \tilde{t}_{(C1)}, \widetilde{LS}_{(J1b)} - \tilde{t}_{(C1)})$$
$$= \min\{(18,28,40) - (3,5,7), (27,55,90) - (3,5,7)\}$$
$$= \min\{(15,23,33), (24,50,93)\}$$

With the same λ value, the ranking value for (15,23,33) and (24,50,93) with $X_1 = 15$ and $X_2 = 93$ can be calculated by using equation 6. Based on the ranking value, it is obtained $\widetilde{LS}_{(C1)} = (15,23,33)$.

Table 6. Backward Pass by FLASH

Activity Code	FLS			FLF		
	a	m	b	a	m	b
A	0	0	0	1	2	3
B1	13	20	28	15	23	33
B2	1	2	3	15	23	33
C1	15	23	33	18	28	40
C2	18	28	40	32	58	85
D1	32	58	85	33	60	88
D2	33	60	88	35	64	94
D3	35	64	94	36	66	97
D4	36	66	97	37	68	100
D5	37	68	100	39	71	104
D6	39	71	104	40	73	107
E	40	73	107	41	75	110
F1	41	75	110	43	77	113
F2	43	77	113	44	79	116
G	44	79	116	45	80	118
H	45	80	118	46	82	121
I	46	82	121	48	84	124
J1a	25	52	86	27	55	90
J1b	27	55	90	31	61	97
J1c	31	61	97	35	67	104
J1d	35	67	104	38	71	109
J1e	38	71	109	48	84	124
J1f	48	84	124	78	129	184
J1g	78	129	184	80	132	188
J1h	80	132	188	82	135	192
J1i	82	135	192	84	138	196
J2a	84	138	196	86	141	200
J2b	86	141	200	88	144	204
J2c	88	144	204	93	151	214
J2d	93	151	214	103	163	228
J2e	103	163	228	104	165	231
J2f	104	165	231	105	167	234
J2g	105	167	234	106	169	237

Based on the computation, it can be calculated the slack of the activities by the equation 7. The result of slack is the same with CPM's result, and also the critical path, as follows:

Table 7. Slack by FLASH

Activity Code	Float			Desc.
	a	m	b	
A	0	0	0	Critical
B1	12	18	25	Uncritical
B2	0	0	0	Critical
C1	0	0	0	Critical
C2	0	0	0	Critical
D1	0	0	0	Critical
D2	0	0	0	Critical
D3	0	0	0	Critical
D4	0	0	0	Critical
D5	0	0	0	Critical
D6	0	0	0	Critical
E	0	0	0	Critical

Activity Code	Float			Desc.
	a	m	b	
F1	0	0	0	Critical
F2	0	0	0	Critical
G	0	0	0	Critical
H	0	0	0	Critical
I	0	0	0	Critical
J1a	22	47	78	Uncritical
J1b	9	27	50	Uncritical
J1c	9	27	50	Uncritical
J1d	9	27	50	Uncritical
J1e	9	27	50	Uncritical
J1f	0	0	0	Critical
J1g	0	0	0	Critical
J1h	0	0	0	Critical
J1i	0	0	0	Critical
J2a	0	0	0	Critical
J2b	0	0	0	Critical
J2c	0	0	0	Critical
J2d	0	0	0	Critical
J2e	0	0	0	Critical
J2f	0	0	0	Critical
J2g	0	0	0	Critical

Based on the Table 7, the critical path is obtained as the same as CPM, i.e. A-B2-C1-C2-D1-D2-D3-D4-D5-D6-E-F1-F2-G-H-I-J1f-J1g-J1h-J1i-J2a-J2b-J2c-J2d-J2e-J2f-J2g.

Probability of Completion Time

To determine the probability is using the membership function of the last activity from network planning as shown on Figure 4. The last activity is J2g, so the calculation of probability in conducted based on the membership function of of $\widetilde{\mathrm{E}}\mathrm{F}_{\mathrm{J2g}}$ or $\widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}}$. Membership function of $\widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}}$, as follows:

$$\mu_{(\widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}})} = \begin{cases} 0; \widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}} < 106 \text{ or } \widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}} > 237 \\ \dfrac{\widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}} - 106}{63}; 106 \leq \widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}} \leq 169 \\ \dfrac{237 - \widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}}}{68}; 169 \leq \widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}} \leq 237 \end{cases}$$

By using completion time of 179 days, the equation to be used is $\frac{237-\widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}}}{68}; 169 \leq \widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}} \leq 237$. Thus, the computation of probability as follows:

$$\frac{237 - \widetilde{\mathrm{L}}\mathrm{F}_{\mathrm{J2g}}}{68} = \frac{237 - 179}{68} = 0{,}8529$$

Thereby, the probability is obtained in the amount of 0,8529 or 85,29% the probability of the porject can be completed in 179 days. This probability value means that the project can be finish within 179 days reaching a probability of 85,29% between the fastest time 169 days and the slowest time 237 days.

CONCLUSION

Based on the research, project scheduling with the FLASH method obtained a total completion time of 106 days optimistic time, 169 days most likely time, and 237 days pessimistic time. FLASH considers the whole activities of the project with the flexibility of three estimation time. By the target time of 179 days that was obtained from CPM, the probability is in the amount of 85,29%. Thereby, the FLASH method is recommended to be applied in project scheduling. Future research is expected to have a more precise duration for each activity, thus producing the nearest to the actual time by history or subjective.

REFERENCE

Ashwini Mate, M. A., & Keswani, I. P. (2014). Scheduling By Using Fuzzy Logic in Manufacturing. *International Journal of Engineering Research and Applications*, 4(7), 104–111.

Devi, T. R., & Reddy, V. S. (2012). Work Breakdown Structure of the Project. *International Journal of Engineering Research and Applications*, *2*(2), 683–686.

Elizabeth, S., & Sujatha, L. (2013). Fuzzy critical path problem for project network. *International Journal of Pure and Applied Mathematics*, *85*(2), 223–240. https://doi.org/10.12732/ijpam.v85i2.4

Firstdhitama, W., Suastika, I. K., & Ma'ruf, B. (2018). Perencanaan Penjadwalan Reparasi Kapal Ferry Dengan Menggunakan Metode Flash. *Jurnal Wave: Jurnal Ilmiah Teknologi Maritim*, 12(1), 1–12. https://doi.org/10.29122/jurnalwave.v12i1.2869

Gonaly, B., & Shtub, A. (2001). *Handbook of Industrial Engineering: Technology and Operations Management* (pp. 1264–1277). John Wiley & Sons, Inc.

Hakim, T., Maharani, A., & Rachman, F. (2021). Optimalisasi Penjadwalan Proyek Modern Rice Milling Plant (MRMP) Menggunakan Metode Project Evaluation Review Technique (PERT). *Proceedings Conference on Design Manufacture Engineering and Its Application*, *5*(1), 294–298.

Lee, K. H. (2005). *First course on fuzzy theory and applications.* Springer.

Rani, H. A. (2016). Manajemen Proyek Konstruksi. Available from https://elearning.umj.ac.id/pluginfile.php/75285/course/overviewfiles/kuliah ke 9 Manj. proy. konstr..pdf?forcedownload=1

Santosa, B. (2009). *Manajemen Proyek (Konsep dan Implementasi)*. Graha Ilmu.

Trisiana, A., Arifin, S., & Effendy, K. (2020). Penjadwalan Ulang Pekerjaan Finishing Proyek Shangrila Hotel Resort and Spa Menggunakan Metode PERT dan FLASH. *Jurnal Rekayasa Teknik Sipil Dan Lingkungan*, *4*, 119–130.

Vizkia, N., Farela, C., & Tantrika, M. (2014). Perbandingan Metode PERT Dan Fuzzy Logic Application For Schedulling (FLASH) Pada Penjadwalan Proses Fabrikasi Boiler (Studi Kasus: PT Indonesian Marine Corp. Ltd.). *Jurnal Rekayasa Dan Manajemen Sistem Industri*, *2*, 482–494.

Widiasanti, I., & Lenggogeni. (2013). *Manajemen Konstruksi*.