Analysis of Earned Value and Project Crashing Methods on High Rise Building Project Scheduling (Case Study: Sky House BSD+ Apartment Project)

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Abstract

The purpose of this study is to analyze how much time delays in project implementation using the earned value analysis method and re-scheduling in the remaining implementation time using the project crashing method on the Sky House BSD+ Apartment construction project, BSD City, South Tangerang, Banten. The method used in this research is the Earned Value Analysis method and the Project Crashing method. The results showed that the time performance in the implementation of this project work was delayed in the 4th week to the 32nd week, with a negative value of the Schedule Variant (SV) of Rp.20,727,722,053.85 and the Time Performance Index (SPI) value is less than 1 that is 0.46 (SPI= 0.46<1). Thus, the normal time duration becomes 258 days and causes an increase of 98 calendar days from the initial project schedule. After the project runs or lasts for 32 weeks or 160 working days, re-scheduling is carried out by increasing the number of workers using the Project Crashing method and it is found that it still takes a duration of 83 days, so that the total duration of Project Crashing becomes 243 days from normal time is 258 days. Thus, the acceleration of duration using the Project Crashing method obtained a total time efficiency of 15 days (saving time).

Keywords
Earned value analysis method, project crashing method, schedule variance, schedule performance index and re-scheduling

1. Introduction
The Sky House BSD+ Apartment construction project in August 2020, the process is still at the stage of building structure work. The project, which began in January 2020 and is targeted to be completed in December 2022, is unavoidable from the risk of delays. This is due to the magnitude of the workload and the height of the housing to be built with a fairly narrow time limit for the implementation of the construction process. The completion of the Sky House BSD+ Phase II Apartment Tower construction project was delayed due to several factors, one of which was the unfavorable weather in the afternoon.

The earned value method is one of the tools used in project management that integrates cost and time. The earned value method presents 3 (three) dimensions, namely: the physical completion of the project (the percent complete) which reflects the planned cost absorption (budgeted cost), the actual costs that have been incurred or what are called actual costs, and the percentage of completion of the costs already incurred budgeted or what are called earned value. From these three dimensions, various factors can be calculated that indicate the progress and performance of project implementation such as cost variance (CV), time variance or schedule variance (SV), work productivity index (CPI), time productivity index (SPI), forecasts project completion costs (EAC), and project completion schedule estimates (ECD). The results of the project performance evaluation can be used as an early warning if there is poor performance in project completion so that management policies and changes in implementation methods can be carried out so that cost overruns and project completion delays can be prevented (Ugural and Burgan 2021).

While, project crashing is to reduce the time of a job that will affect the project completion time. Crashing method is a deliberate, systematic, and analytic process by testing all activities in a project centered on activities that are on the

critical path. Project Crashing by estimating the variable cost in determining the maximum and most economical reduction in duration of an activity that is still possible to be reduced (Ulfa and Suhendar 2021).

Therefore, this study will conduct an analysis of time performance (time delays in project scheduling) and cost performance (swelling of project implementation costs) using the Earned Value Analysis method and also rescheduling simulations on jobs that experience time delays (which has not been completed) in the remaining time of the implementation of the ongoing Sky House BSD+ Apartment construction project using the Project Crashing method.

2. Literature Review

In this literature review, there are several examples of research that has been carried out from previous researchers' journals or research papers as a guide for comparative research materials to be carried out.

The following is a literature review (journals) that uses the Earned Value Analysis method:

a. "Earned Value Management System in Indonesian Construction Projects" shows that in term of time, 3 buildings were completed ahead of schedule and 1 building was delayed. Meanwhile in term of cost, 3 buildings are lower than the budgeted cost, whereas 1 building is higher than the budgeted cost (Priyo 2021).

b. "Effective Performance Evaluation to Estimate Cost and Time using Earned Value" shows that the Schedule Performance Index (SPI) obtained a value of 0.58. Project progress in the field shows that the project experienced a delay of 41.48%. It can be seen from the initial project plan of 99.06%, but at the time of review the realization was only 57.22%. In terms of costs, the Cost Performance Index (CPI) is 1.25. This shows that the costs incurred during the review are still smaller than the existing budget plan. At the end of the review period, the final project cost estimates, both direct and indirect costs, are obtained. With the tendency of project performance at the time of review, the value is still less than the project budget, while the estimated project completion time will be longer or late by about 56.52% of the planned schedule (Susilowati and Kurniaji 2020).

c. "Project Performance Evaluation Using EVA Technique: Kotay Bridge Construction Project on Kayto River in Afghanistan" shows that the application of the EVA technique in the bridge construction project was presented and the data was taken directly from the project site office. Construction started in February 2016. The project duration as originally scheduled was 317 calendar days. Tracking to 1 July 2016 revealed 49% overall project completion. Studies reveal that CPI and SPI are both less than 1.0 which means that the project is not well done, time and cost overruns are also clearly shown. TCPI = 1.06>1 indicates that the remaining amount of project work must be carried out more effectively and at a better cost performance level than the work carried out by the project (Ugural and Burgan 2021).

d. "Automated Calculation of Earned Value Analysis on Construction Project using C# Programming" shows that there are 3 National Gudang Garam buildings, namely in North Aceh, Pati, and Pamekasan, which have good time performance, which means the project is carried out according to the specified schedule, and poor cost performance resulting in a loss of Rp. 251,380 up to Rp. 847,377. Meanwhile, for the other 3 (three) National Gudang Garam buildings, namely in the Indramayu, Demak, and Jepara areas, they have poor time performance, which means there is a delay in the projects, and poor cost performance resulting in losses of Rp. 1,168,999 to with Rp. 9,916.102 (Desmanto and Sulistio 2021).

e. "Time Control Evaluation on the Construction of Health Building using the Earned Value Analysis Method" shows that the development project for the Basic Essential Neonatal Obstetrics Service of PUSKESMAS, Parigi District, Pangandaran Regency experienced delays. The delay can be seen from the cumulative calculation based on the 2nd week that the number of SVs is negative, namely Rp.-7,075,011.79 and the SPI is worth less than 1, which is 0.932 so that it can be seen that the estimated project completion time will increase by 9 calendar days or become 144 calendar days from the initial project plan schedule. Overcoming this, the contractor in the 17th week made a decision to add a work system in the form of a work overtime system for 1 week by starting work

from 16:00 WIB, then taking a break from 18:00 to 19:00, and continuing overtime work until 22:00 WIB, so the project was successfully completed on time (Maskur 2021).

f. "Earned Value Analysis on the Project Construction of Bukittinggi Santika Hotel" shows that the project's performance was delayed, this can be seen from the calculation data for the analysis of project performance appraisal SV < 0 and from the schedule performance index, SPI < 1 (Honesti and Wiranto 2021).

The following is a literature review (journals) using the project crashing method:

a. "Optimization of Time and Cost for a Research Project by Project Crashing Method" shows that a significant reduction in project duration with a normal increase in project costs. A small increase in project costs with a reduction of almost 45 days in the project interval was observed. Nearly 5% increase in project costs was seen with 15% reduction in total project duration (Sharma et al. 2020).

b. "Reducing Project Duration Of An Apartment Project by Waskita Karya Using Crashing Method" shows that from the calculation of the Crashing method, this project can be optimally reduced to 39 months but will increase the total project cost to Rp.618.665.777.827 which is the same as the additional price of Rp.4,038,705,859 (Ririh and Hidayah 2020).

c. "Time Acceleration Analysis and Optimal Cost of Hospital Hospital Development Project on Ship Building using Critical Path Method (Case Study: PT. PAL INDONESIA (PERSERO))" shows that the calculation of the project in the initial conditions with the initial working day without using overtime hours PT PAL Indonesia (Persero) costs Rp.5,299,631,000, while the Crashing Method is through the addition of 1 hour/day overtime so that project implementation can be accelerated from implementation initial 450 days to 412 days and PT. PAL Indonesia (Persero) issued a project cost of Rp.5,323,752,480 (Tresnadi et al. 2021).

d. "Application of the CPM and Crashing Method in the Jember University Training Center Building Project" shows that through the analysis of CPM and crashing, the optimum time due to additional working hours was obtained for a duration of 364 days, the difference between the normal duration of 97 days and a total cost of Rp. 5,840,312,916. Meanwhile, by using additional labor, it was obtained 374 days, the difference between the normal duration of 88 days was obtained at a cost of Rp. 4,412.522,242 (Putri et al. 2021).

e. "The Implementation of Critical Path Method on the Synthesis Residence Kemang Project" shows that the completion of the project can be completed faster with a crash time of 115 days and there is an additional project cost of Rp.741,493,128 from the normal cost with a normal time of 369 days. This shows that there is time efficiency but there is an increase in costs. So, the total cost required for the completion of the Synthesis Residence Kemang project using the CPM (Critical Path Method) method is Rp. 62.852.324.528 from Rp. 62.110,831,400 (Ulfa and Suhendar 2021).

f. "Time Acceleration Analysis against the Contractor's Cost (Case Study: Kozko Citraland Project – Surabaya)" shows that the completion of the Kozko Citraland Surabaya construction project could be faster than the normal 366 days to 334 days. And it was found that the efficiency of project execution time was 8.74% with a difference in acceleration of 32 working days, from acceleration results obtained an optimal cost of Rp.41.666.3000.914 from the normal cost of Rp.41.690.000.000 for cost efficiency is 0.06% with the difference in costs is Rp.23.699.086 (Saputra et. al. 2020).

3. Research Methodology

Data collection is carried out by collecting literature study materials, either in the form of books that have been published in general or by developing research that has been carried out previously, as well as a combination of project primary data and project secondary data carried out in the context of the data collection process. The primary data used in this study are the project's budget plan, planned S curve or time schedule, and project drawings (for Construction) data. Meanwhile, the secondary data used in this study are weekly project report data, monthly project reports, and actual or realization S curve.

In this study, data analysis was carried out using the Earned Value Analysis method in advance to predict whether projects that were already running had time delays and how much delay the progress of project implementation work

was. Then proceed with performing rescheduling simulation calculations on jobs that experience time delays (which have not been completed) in the remaining time of project implementation that is already running by using the Project Crashing method as a time saving solution for project implementation so that project time delays can be minimized or prevented. The last step is to analyze the comparison of the difference in the total duration of time (time efficiency) between the total duration of time if the work that has time delays (which has not been completed) is continued at a constant rate of progress with the total time of rescheduling work after it has been done acceleration with the Project Crashing Method.

4. Result and Discussion

4.1 Earned Value Analysis

The calculation of the earned value analysis to calculate the schedule variance and the schedule performance index can be seen in Table 1.

Table 1. Earned Value Analysis

Week	Completion Plan (%)	Completion Realization (%)	Schedule Variance (Rp)	Schedule Performance Index
1	1.04	0.62	-160,166,342.85	0.60
2	1.04	1.41	-19,875,797.22	0.97
3	1.04	1.38	109,004,993.16	1.09
4	2.84	1.38	-447,953,747.71	0.80
5	2.84	1.52	-951,666,964.04	0.72
6	2.84	1.55	-1,443,970,425.12	0.67
7	2.84	1.30	-2,031,355,180.01	0.63
8	2.84	0.87	-2,782,279,760.29	0.58
9	2.73	0.78	-3,522,785,276.77	0.54
10	2.73	0.79	-4,259,487,541.50	0.51
11	2.72	0.87	-4,964,283,940.43	0.49
12	2.44	0.79	-5,590,979,732.76	0.47
13	2.43	0.85	-6,193,606,014.54	0.46
14	3.09	0.83	-7,052,777,270.82	0.45
15	3.05	0.76	-7,923,164,036.34	0.43
16	4.13	0.60	-9,263,978,982.00	0.40
17	3.71	0.70	-10,408,506,639.36	0.38
18	4.00	0.60	-11,703,233,049.09	0.36
19	5.14	1.24	-13,186,869,660.73	0.35
20	4.95	3.61	-13,695,628,378.38	0.38
21	5.04	0.66	-15,362,200,913.75	0.36
22	5.12	1.88	-16,593,661,913.60	0.36
23	5.19	1.94	-17,829,447,273.71	0.36
24	5.28	1.95	-19,094,943,998.44	0.37
25	5.29	1.96	-20,362,780,487.79	0.37
26	4.99	2.05	-21,480,694,107.43	0.37
27	3.82	7.25	-20,174,463,842.09	0.43
28	2.88	0.93	-20,914,997,222.11	0.43
29	2.57	2.32	-21,011,185,004.54	0.44
30	1.36	2.11	-20,727,722,053.85	0.46

4.2 Time Control Effectiveness

From Table 1. For Schedule Performance Index (SPI), the results are:

- Amount of data = 30 weeks;
- Result > 1 = 3 weeks;
- Result < 1 = 27 weeks;
- Expected score = 0.9;

So that the score is obtained $= \frac{3}{27} = 0.11$

$= \mathbf{0.11} \times 0.90 = 0.099.$

The result of the parameter for time with a score of 0.099, means that the work is completed late from the planned schedule. Thus, the value of the time control effectiveness of the Sky House BSD+ Apartment Project is 0.099, this value is far from the expected value of 0.90, and therefore in the next sub-point rescheduling will be carried out using the project crashing method, as a solution of the project delay.

4.3 Cumulative Work Progress Analysis

The calculation of the cumulative work progress analysis can be seen in Table 2.

Table 2. Calculation of the Cumulative Percentage of Work Progress If the Project is continued at a Constant Speed without Performing the Duration Acceleration Method

Weeks	Execution time	Plan Percentage (%)	Actual Percentage (%)	Earned Value Percentage (+/-) (%)
1	06 January s/d 12 January	1.04	0.62	-0.42
2	13 January s/d 19 January	2.08	2.03	-0.05
3	20 January s/d 26 January	3.12	3.41	0.29
4	27 January s/d 02 February	5.97	4.79	-1.18
5	03 February s/d 09 February	8.81	6.31	-2.50
6	10 February s/d 16 February	11.66	7.86	-3.80
7	17 February s/d 23 February	14.50	9.16	-5.34
8	24 February s/d 02 March	17.35	10.83	-6.52
9	03 March s/d 09 March	20.07	11.61	-8.46
10	10 March s/d 16 March	22.80	12.40	-10.40
11	17 March s/d 23 March	25.52	13.27	-12.25
12	24 March s/d 30 March	27.96	14.06	-13.90
13	31 March s/d 06 April	30.40	14.91	-15.99
14	07 April s/d 13 April	33.48	15.74	-17.74
15	14 April s/d 20 April	36.53	16.50	-20.03
16	21 April s/d 27 April	40.66	17.10	-23.56
17	28 April s/d 04 May	44.37	17.80	-26.57
18	05 May s/d 11 May	48.37	18.40	-29.97
19	12 May s/d 18 May	53.51	19.64	-33.87
20	19 May s/d 25 May	58.46	23.25	-35.21
21	26 May s/d 01 June	63.50	23.91	-39.59
22	02 June s/d 08 June	68.62	25.79	-42.83
23	09 June s/d 15 June	73.81	27.73	-46.08
24	16 June s/d 22 June	79.09	29.68	-49.41
25	23 June s/d 29 June	84.38	31.64	-52.74
26	30 June s/d 06 July	89.37	33.69	-55.68
27	07 July s/d 13 July	93.19	40.94	-52.25
28	14 July s/d 20 July	-	-	-
29	21 July s/d 27 July	-	-	-

30	28 July s/d 03 August	96.06	41.87	-54.19
31	04 August s/d 10 August	98.64	44.19	-54.45
32	11 August s/d 17 August	100.00	46.30	-53.70
33	18 August s/d 24 August	-	49.00	-51.00
34	25 August s/d 31 August	-	51.70	-48.30
35	01 September s/d 07 September	-	54.40	-45.60
36	08 September s/d 14 September	-	57.10	-42.90
37	15 September s/d 21 September	-	59.80	-40.20
38	22 September s/d 28 September	-	62.50	-37.50
39	29 September s/d 05 October	-	65.20	-34.80
40	06 October s/d 12 October	-	67.90	-32.10
41	13 October s/d 19 October	-	70.60	-29.40
42	20 October s/d 26 October	-	73.30	-26.70
43	27 October s/d 02 November	-	76.00	-24.00
44	03 November s/d 09 November	-	78.70	-21.30
45	10 November s/d 16 November	-	81.40	-18.60
46	17 November s/d 23 November	-	84.10	-15.90
47	24 November s/d 30 November	-	86.80	-13.20
48	01 December s/d 07 December	-	89.50	-10.50
49	08 December s/d 14 December	-	92.20	-7.80
50	15 December s/d 21 December	-	94.90	-5.10
51	22 December s/d 28 December	-	97.45	-2.55
52	29 December s/d 04 January	-	100.00	0.00

So after the 32nd week or the ongoing project, the project is continued at a constant speed without using the duration acceleration method, then the normal duration time (calculated from the beginning of the project until the project progress is 100% or the project delay ends) is 258 working days or in week 52 of the construction of the project.

4.3 Crashing Analysis

Acceleration of duration is done by adding the number of workers, but the number of working hours remains 2 shifts, namely 08.00-12.00 and 13.00-17.00, the overtime is not applied. Because from the analysis of the previous earned values calculation method, it was found that the implementation of the project work had experienced a delay in time and costs incurred were still below the planned budget at the initial stage of the project (cost underrun). Thus, if the acceleration of duration is carried out by increasing working hours (imposing overtime hours), it is predicted that it will add quite a large cost (above the planned budget or cost overrun) because the cost of overtime wages is generally the same as the daily cost of workers' wages (normal work + overtime hours = 2 × daily wage). Meanwhile, the reason for choosing fixed working hours of 2 shifts instead of 3 shifts is because working at night until midnight is not effective on the performance of project workers, because in general people are tired.

The composition of 1 (one) group of workers before the acceleration is divided into 2 (two) shifts, namely:

a. Foreman = 1 person;
b. Ordinary workers = 6 people;
c. Specialized workers (such as masons, carpenters) = 2 people.
d. Number of workers = 9 workers.

Acceleration is carried out by adding 3 (three) workers into 1 (one) group of workers divided into 2 (two) shifts, namely:

a. Foreman = 1 person;
b. Ordinary workers = 8 people;
c. Specialized workers (such as masons, carpenters) = 3 people.
d. Number of workers = 12 workers.

Based on the crashing analysis, the critical path and the sequence of the project work detail can be seen in Figure 1 and Table 3.

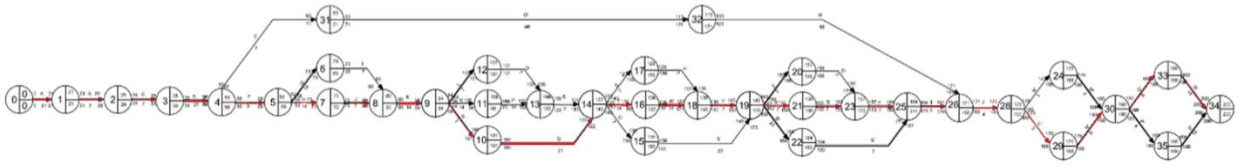

Figure 1. The Critical Path of the Accelerated Construction of Sky House BSD+ Apartment

Table 3. The Relation of Work in the Construction of Sky House BSD+ Apartment with the Implementation of the Project Crashing Method

ID	Job Description	Normal Predecessors	Project Crashing Predecessors
A	**STRUCTURE**		
10	CONCRETE STAIRS	24SS+6 days	24SS+6 days
B	**ARCHITECTURE**		
11	BRICK WORK	15SS	15SS
12	ACCESSORIES WORK	31SS+6 days	31SS+6 days
13	DOOR, WINDOW AND PARTITION WORK	34SS+6 days	34SS+6 days
14	PLASTERING WORK	29SS+34 days	29SS+30 days
15	CERAMIC FLOOR WORK	32SS+42 days	32SS+42 days
16	CEILING WORK	33SS+12 days	33SS+12 days
17	SANITARY WORK	30SS	30SS
18	PAINTING WORK	30SS+18 days	30SS+16 days
C	**PLUMBING**		
19	PLUMBING WORK	25	25
20	DIRTY WATER PIPING & FITTING	38SS	38SS
21	CLEAN WATER PIPING & EQUIPMENT	39SS+6 days	39SS+6 days
22	PROCUREMENT / INSTALLATION OF CLEAN WATER PUMP	39SS	39SS
D	**FIRE FIGHTING SYSTEM**	**41SS**	**41SS**
23	HYDRANT & EQUIPMENT PROCUREMENT	42SS	42SS
24	PROCUREMENT / INSTALLATION OF HYDRANT PUMPS & EQUIPMENT	43SS	43SS
25	GUTTER & CHANNEL WORK	29SS+6 days	29SS+6 days
26	FIRE DETECTOR / ALARM SYSTEM	44SS	44SS
E	**ELECTRICAL WORK**		
27	PANEL WORK	49	49
28	LIGHTING / ARMATURE INSTALLATION WORK	29	29
29	PROCUREMENT / INSTALLATION OF FEEDER / TRAY CABLES	49SS+18 days	49SS+18 days
30	AIR CONDITIONING (MULTI-V IV) WORK	50SS	50SS
31	PROCUREMENT / INSTALLATION OF ELEVATOR & ESCALATOR PASSANGER	26	26
32	LIGHTNING DISTRIBUTOR	25	25

From the scheduling that has been programmed using Microsoft Project 2016 with the Project Crashing method after the 32nd week, it is found that it still requires a duration of 83 days. Thus, the total duration from the beginning

of the project followed by an acceleration of duration by increasing the number of workers using the Project Crashing method after the 32nd week or after the project is running or in progress is:

The Total Time Project Crashing Duration:
= Total duration of the 1st weeks to the 32nd week + project crashing time added
= 160 days + 83 days = 243 days.

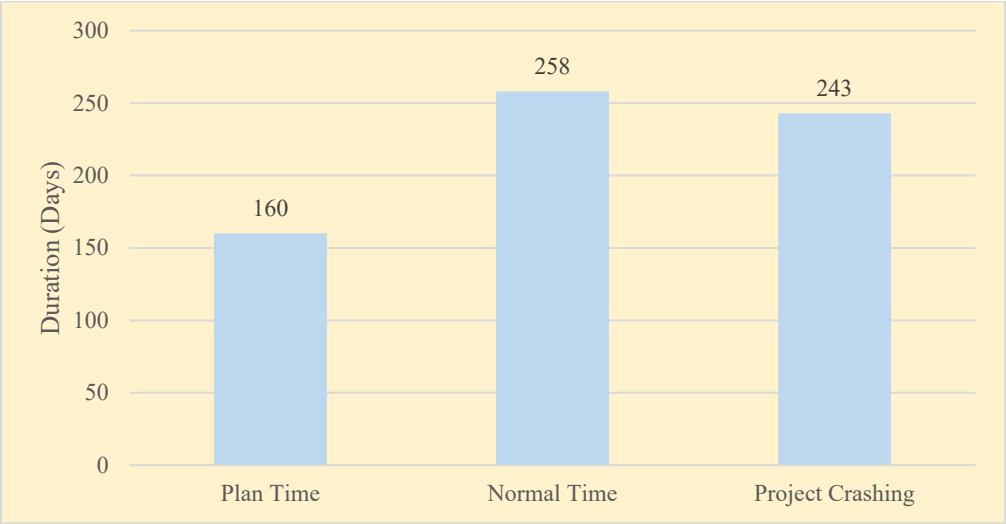

Figure 2. Results of the Accelerated Construction of Sky House BSD+ Apartment

After the 32nd week, rescheduling was carried out using the Project Crashing method and it was found that it still needed a duration of 83 days, so that the total duration of Project Crashing became 243 days from the normal time of 258 days. Thus, it means that by accelerating the duration by increasing the number of workers using the Project Crashing method, the total time efficiency of the duration (time saving) is 15 days. This result can be seen in Figure 2.

5. Conclusion

The followings are the conclusions of this research:

a. By using the earned value analysis method, it was found that the time performance in the implementation of this project work was delayed in the 4th week to the 32nd week, with a negative value of the Schedule Variant (SV) of Rp.20,727,722,053.85 and the Schedule Performance Index (SPI) is less than 1, which is 0.46 (SPI= 0.46<1). Thus, the normal time duration becomes 258 days (if the delayed project work is continued at a constant speed, without the duration acceleration method being used) from the planned time of 32 weeks or 160 days, and causes an increase of 98 calendar days from the initial project plan schedule.

b. After the project runs or lasts for 32 weeks or 160 working days, rescheduling is carried out by increasing the number of workers using the Project Crashing method and it is found that it still takes a duration of 83 days, so that the total duration of Project Crashing becomes 243 days from normal time is 258 days.

c. The total plan time duration (Plan S Curve) is completed in the 32nd week or 160 business days. The total normal time duration (if the delayed project work is continued at a constant speed, without the duration acceleration method being applied) is 258 days. Meanwhile, by rescheduling using the Project Crashing method, it was found that it still needed a duration of 83 days, so that the total duration of Project Crashing became 243 days. Thus, it

means that by accelerating the duration by increasing the number of workers using the Project Crashing method, the total time efficiency of the duration (time saving) is 15 days.

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Biographies

Putri Arumsari joined the Civil Engineering Department of Binus University in November 2015 as a lecturer. She graduated her Bachelor Degree in Civil Engineering from Binus University in 2011 and graduated her Master Degree in Infrastructure Management from Universitas Indonesia in 2015. She currently doing her Doctoral Degree in Construction Management in Universitas Tarumanagara. Her main interest in research is about building maintenance and have written several proceedings and journals on the topic.

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