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Analysis of Project Performance and Completion Time Using Evm and Cpm-Pert Methods (Case Study of Road Reconstruction Project)

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Abstract

The implementation of physical work requires good project control because various conditions can affect the construction implementation process. The calculation of performance analysis is carried out with Earned Value Management (EVM) and the determination of project completion time is carried out by the CPM-PERT method. In this research, it was found that in the 26th week, the schedule performance index value was 0.75758 with an estimated project completion time using the EVM method of 242 days. The critical path shown by the CPM method is M - G - H - N - F - D - E - P - O - K - B – A with a total project completion time of 274 days. Based on the PERT method, the probability of completion time for the project is 71.90%. Acceleration is carried out using the CPM critical path with an optimistic duration of PERT. This acceleration can be done by optimizing the project completion time to 256 days.

Keywords: EVM; CPM; PERT.

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1. Introduction

Banyuwangi Regency is a regency located in the eastern part of East Java Province. Banyuwangi Regency is one part of the district that participates to accelerate local economic growth through the tourism industry [1]. The availability of road infrastructure with good conditions is needed to facilitate access to tourist attractions. One of the improvements in road infrastructure services implemented is Project XYZ. The existing condition of the road body width is between 4 m to 5 m. Based on these conditions, rehabilitation or functional maintenance of roads is needed to facilitate access to tourist attractions in the area.

In infrastructure development, various possibilities can occur and potentially hinder the development process[2]. The implementation of physical work requires good project control because various conditions can affect the construction implementation process. These various conditions can affect the implementation of construction which will later have an impact on the cost and time of project completion. The success of a project can be seen from the achievement of the targets set, namely completed on ticompletingst and meeting the required quality specifications [3,4]. The implementation of infrastructure development must be completed with a predetermined time and cost. Estimation of cost and time estimates is carried out taking into account many conditions with a certain degree of probability.

This research was motivated by the application of a control system in the project. One of the control systems in the project can be done by predicting the development of costs and completion time as project performance parameters. Earned Value Management (EVM) is a technique for measuring project performance that aims to measure and evaluate actual project progress to complete projects on time and within budget [5]. EVM itself is an ideal method because it can integrate time and cost so that it can know the progress of a project faster or later than the project schedule should be and to know bigger or smaller than the budget should be [6]. Cost predictions and execution time using EVM are linear so they do not represent non-linear conditions such as the influence of project resources [7] and do not provide information about prediction limits [8]. Determination of project completion time can be done with Critical Path Method (CPM)[9, 10, 11] and Project Evaluation Review Technic (PERT)[12, 13]. Previous studies have been conducted to predict project completion times by combining CPM and PERT methods[14, 15, 16], but no project acceleration plan has been determined according to the contractor's capabilities. The application of PERT and CPM methods, especially for road improvement projects, can make it easier for managers when mapping problems during the project implementation period so that the time and costs used can be controlled properly and the critical path in project work can be mapped properly [17].

2. Research Method

2.1. Earned Value Management (EVM)

The method of implementing cost and schedule control is known as the Earned Value Management method. This concept is a concept of calculating the budgeted cost of works performed [18]. This method measures the size of the unit of work that has been completed, at any given time, by assessing it based on the amount of budget available for the work. Cost control systems generate performance reports and project cost predictions.

While schedule control produces a project completion status report. Assessment of value concept elements to analyze project performance include Schedule Variance (SV), Schedule Performance Index (CPI), and Estimated Completion Date (ECD).

The indicators used in this method are Earned Value and Planned Value[19, 20]. Earned Value is the value received from the completion of work over a certain period of time calculated based on the accumulation of completed work[21].

Planned Value is a cost budget allocated based on a work plan that has been prepared against a certain time calculated from the accumulated budget costs planned for work in a certain period of time [21, 22].

Schedule Variant (SV) is the difference between the part of the work that can be carried out and the part of the work planned [23, 24].

A positive value of the variant schedule indicates that in that time period more work was completed than planned[25]. In other words, part of the work is completed faster than the plan.

$$SV = EV - PV \quad \text{..... (1)}$$

Where:

SV : Schedule Variants

EV : Earned Value (the value received from completing the performance over a period of time)

PV : Planned Value (costs allocated based on a work plan prepared against time)

Schedule Performance Index (SPI) is a comparison between the completion of work in the field with a work plan in a certain period of time. The effect of the magnitude of the SPI value is shown in **Table 2.1.**

$$SPI = \frac{EV}{PV} \quad \text{..... (2)}$$

Table 2.1: Schedule performance values.

Performance Index	Grades <1	Value = 1	Grade>1
SPI	Project faster	Projects on time	Project faster

(Source:[26])

Based on the calculated schedule performance index value, it can be determined the estimated completion date / time estimate [3], with the following formula.

$$Te = Time\ Usage + \left(\frac{Time\ Total - Time\ Usage}{SPI}\right) \quad \text{..... (3)}$$

2.2. Critical Path Method (CPM)

Critical Path Method (CPM) is a project management technique used to plan, schedule, and control projects. The critical path method is used to estimate the minimum project duration and determine the amount of schedule flexibility on logical network paths in the jadwal model [23]. The critical path is the path with the activity component with the longest total amount of time and shows the fastest time to complete the project [27]. CPM is a fundamental quantitative technique developed for project management assuming deterministic turnaround times [28]. CPM helps in identifying the critical path, which is the sequence of activities that must be completed on time for the project to be completed within the given deadline [4].

2.3. Project Evaluation and Review Technique (PERT)

Project Evaluation and Review Technique (PERT) is a project management tool used to plan, schedule, and coordinate tasks within a project. PERT is used to plan and control project duration, stages analyze each activity with three time scopes, namely optimistic time, pessimistic time, and realistic time to get an estimate of expected time [29]. PERT is a network model capable of mapping the completion time of different activities [30]. PERT construction is about breaking down a construction project into smaller, more manageable tasks, then using network diagrams to map dependencies between those tasks. The indicators used in the PERT method are as follows:

Standard deviation of activities.

$$S = \frac{b-a}{6} \quad \text{..... (4)}$$

Estimated time for completion of all activities

$$Te = \frac{a+4m+b}{6} \quad \text{..... (5)}$$

Variants of activities

$$V = S^2 \quad \text{..... (6)}$$

Probability of occurrence of estimated completion time

$$Z = \frac{T_d - T_e}{\sqrt{\sum V}} \quad \text{..... (7)}$$

Where:

a : The most optimistic (fastest) activity duration
b : Activity duration most pessimistic (longest)
m : Duration of normal activities

S : Standard deviation

Te : Estimated time to complete

V : Variants of activities

Td : Activity time plan

Z : Probability of occurrence of estimated completion time

3. Research Method

3.1. Project Data

This type of project in this research is a widening of the road to standards. The research location is in Banyuwangi Regency. The project is divided into 3 time periods. Period I is the initial contract value with a nominal value of Rp. 33,499,359,227.22, Period II is the value of the Contract Change Order (CCO) with a nominal value of Rp. 33,499,359,227.22, and Period III is the value of Addendum 01 with a nominal value of Rp. 36,074,638,887.75. The project implementation time is carried out with a span of 227 calendar days or 33 weeks.

3.2. Earned Value Management (EVM)

The Earned Value Management (EVM) method uses several stages before determining the estimated time for project completion. In this case, the analysis used is an analysis of the performance of activity completion time. The first stage is by calculating Planned Value (PV), Earned Value (EV) and Schedule Variant (SV). With the calculated data, the Schedule Performance Index (SPI) value can be determined . SPI data as input in determining the time of completion of activities (Estimate Complete Date).

The calculation of Planned Value (PV) describes the budget of the plan for a certain period against the volume of the project plan. The PV calculation is shown in **Figure 3.1.**

$$PV_{26} = \%\ Cumulative\ Planned \times BAC$$

$$= \%\ 68{,}905 \times Rp.\ 36{,}074{,}638{,}888$$

$$= Rp.\ 24{,}857{,}229{,}925.61$$

The Earned Value (EV) calculation describes the project plan budget for a given period against what has been done at the actual volume of work. The calculation of the EV value is shown in **Figure 3.1.**

$$EV_{26} = \%\ Cumulative\ Result \times BAC$$

$$= \%\ 52.201 \times Rp.\ 36{,}074{,}63{,}888$$

$$= Rp.\ 18{,}831{,}322{,}245.80$$

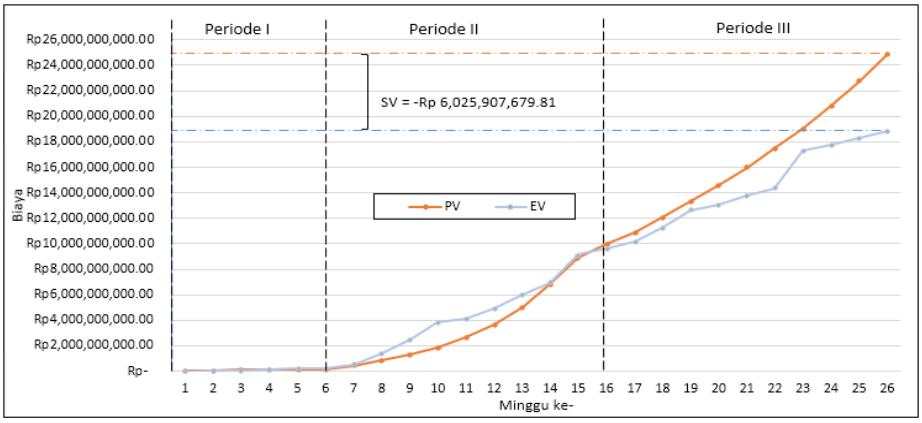

Figure 3.1: PV and EV values.

Schedule Variant (SV) is a review of progress reports on the results of work progress within a certain period of time minus the work progress plan. The SV calculation is shown in **Figure 3.1.**

$$SV_{26} = EV - PV$$

$$= Rp.\,18{,}831{,}322{,}245.80 - Rp.\,24{,}857{,}229{,}925.61$$

$$= -Rp.\,6{,}025{,}907{,}679{,}81$$

Schedule Performance Index (SPI) describes the ratio of values obtained from the comparison between the value of work progress results and work progress plans. The calculation of SPI is shown in **Figure 3.2.**

$$SPI_{26} = \frac{EV}{PV}$$

$$= \frac{\text{Rp. } 18{,}831{,}322{,}245.80}{\text{Rp. } 24{,}857{,}229{,}925.61}$$

$$= 0.75758$$

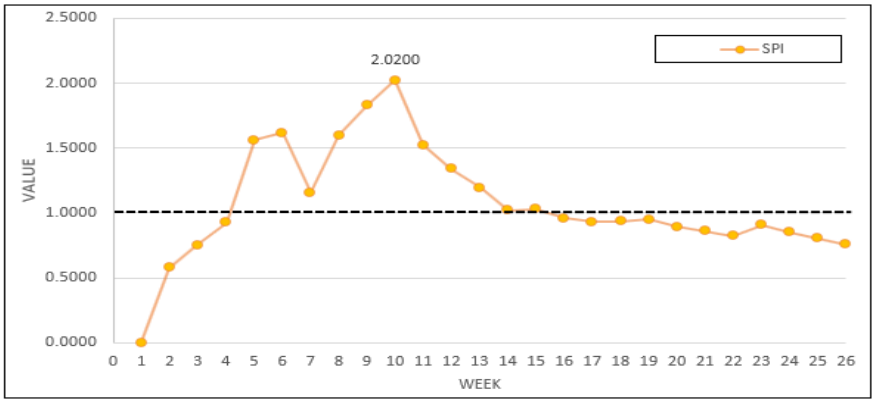

Figure 3.2: Graph of SPI values.

The Estimate Complete Date (ECD) calculation describes the estimated time required to complete a project based on schedule performance over a given period.

$$ECD = Time\ Usage + \left(\frac{Time\ Total - Time\ Usage}{SPI}\right)$$

$$= 26 + \left(\frac{33 - 26}{0.75758}\right)$$

$$= 34.486 \text{ Minggu} \approx 242 \text{ Hari}$$

3.3. Earned Value Management (EVM)

Based on the data obtained up to week 26, activities and remaining volumes that have not been reached can be seen in **Table 3.1.** In this data, the duration of work is the planned duration of service providers for each activity based on production capacity according to Minister of Public Works No. 1 of 2022.

Table 3.1: List of Activities and Duration of Activity.

Code	Activites	Unit	Volume	Plan Duration (Days)
A	Mobilization	Ls	0.30	3.00
B	Environmental Security	Fruit	3.00	2.00
C	Reinforced Concrete Box Culvert	M'	53.00	7.00
D	U-conical channel Type DS 3	M'	360.00	2.00
E	U-conical channel Type DS 3a	M'	720.00	7.00
F	Ordinary Quarry	M^3	2433.16	3.00
G	Road Body Setup	M^2	5091.39	2.00
H	Class B Aggregate Foundation Layer	M^3	908.39	2.00
I	Class S Aggregate Foundation Layer	M^3	374.00	1.00
J	Stone Masonry	M^3	125.43	3.00
K	Thermoplastic Road Markings	M^2	2938.50	8.00
L	Mahogany Tree Type	Fruit	460.00	3.00
M	Widening excavations for hardened road shoulders	M^3	24.85	1.00
N	fc'20 concrete for hardened road shoulder	M^3	1560.02	12.00
O	Laston Surface Coating/Leveler (AC)	Ton	8415.62	33.00
P	Laston Layer Foundation/Grader (ATB/L)	Ton	5072.21	17.00

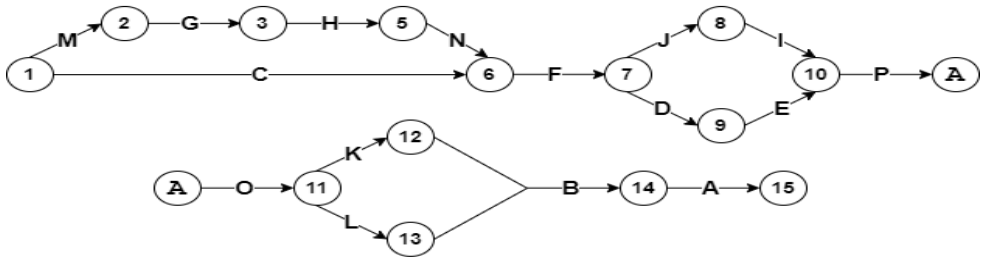

Figure 3.3: Network Planning.

The activity data obtained is then carried out critical trajectory planning based on the sequence of activity implementation. Critical path determination is selected based on the largest number of durations with a given

trajectory. The critical path is selected for the Network Planning path shown in Figure 3.3 and the critical path and its duration are addressed in **Table 3.1**.

Table 3.2: Critical Path Trajectories.

No.	Critical Path	Sequence of Activities	Activity Duration(Days)
1	Critical Path 1	M - G - H - N - F - J - I - P - O - K - B - A	87.00
2	Critical Path 2	M - G - H - N - F - J - I - P - O - L - B - A	82.00
3	Critical Trajectory 3	M - G - H - N - F - D - E - P - O - K - B - A	92.00
4	Critical Trajectory 4	M - G - H - N - F - D - E - P - O - L - B - A	87.00
5	Critical Path 5	C - F - J - I - P - O - K - B - A	77.00
6	Critical Trajectory 6	C - F - J - I - P - O - L - B - A	72.00
7	Critical Trajectory 7	C - F - D - E - P - O - K - B - A	82.00
8	Critical Trajectory 8	C - F - D - E - P - O - L - B - A	77.00

Based on the data in **Table 3.2**, critical path 3 is the chosen trajectory because it produces the largest number of activity durations with a duration of 92 days. Therefore, based on the CPM method, the estimated completion of project activities is 26 weeks of running time plus 92 days, so that it becomes 274 days.

3.4. Project Evaluation and Review Technique (PERT)

The PERT method uses three estimated completion times of project activities, namely the fastest duration (optimistic), normal duration (realistic) and longest duration (pessimistic). In this study, the fastest duration was determined based on the largest production capacity that the provider could ever afford in each activity. The normal duration is based on the time the provider plans to complete each activity, which has been used in the CPM method. The longest duration based on the smallest production capacity ever carried out by a service provider without project constraints.

Table 3.3: PERT Method Calculation.

CODE	**Fastest Duration (a)**	**Normal Duration (m)**	**Longest Duration (b)**	**Standard Deviation**	**Te**	**Variance**
	Day	**Day**	**Day**			
A	2.00	3.00	4.00	0.33	3.00	0.11
B	1.00	2.00	3.00	0.33	2.00	0.11
F	1.00	2.00	3.00	0.33	2.00	0.11
G	5.00	7.00	8.00	0.50	6.83	0.25
H	2.00	3.00	3.00	0.17	2.83	0.03
I	2.00	2.00	3.00	0.17	2.17	0.03
J	1.00	2.00	3.00	0.33	2.00	0.11
K	6.00	8.00	9.00	0.50	7.83	0.25
M	1.00	1.00	1.00	0.00	1.00	0.00
N	8.00	12.00	14.00	1.00	11.67	1.00
O	29.00	33.00	34.00	0.83	32.50	0.69
P	16.00	17.00	19.00	0.50	17.17	0.25
				5.00	91.00	2.94

Based on the calculations that have been done, it can be determined the value of standard deviation, completion time of project activities, and value of variance. The probability value of project completion can be determined

from the following Z value.

$$Z = \frac{T_d - T_e}{\sqrt{\sum V}} = \frac{92 - 91}{\sqrt{2.94}} = 0.58$$

The calculation of the Z value of 0.58 when viewed in the normal probability table shows a result of 0.7190. Thus, the probability of project completion time within 274 days is 71.90%.

3.5. Acceleration of Project Activities

Table 3.4: Project Activity Acceleration Plan.

Code	Work	Sat	Duration of Optimistic Activities	Week to -										
				27	28	29	30	31	32	33	34	35	36	37
A	Mobilization	Ls	2.00											0.3
B	Environmental Security	Fruit	1.00											3.0
C	Reinforced Concrete Box Culvert	M'	6.00	53.0										
D	U-conical channel Type DS 3	M'	1.00		360.0									
E	U-conical channel Type DS 3a	M'	5.00			720.0								
F	Ordinary Quarry	M^3	2.00		2433.2									
G	Road Body Setup	M^2	2.00	5091.4										
H	Class B Aggregate Foundation Layer	M^3	1.00	908.4										
I	Class S Aggregate Foundation Layer	M^3	1.00		374.0									
J	Stone Masonry	M^3	3.00		125.4									
K	Thermoplastic Road Markings	M^2	6.00										2938.5	
L	Mahogany Tree Type	Fruit	3.00										460.0	
M	Widening excavations for hardened road shoulders	M^3	1.00	24.9										
N	Concrete fc'20 (K-250) For Road Shoulder hardened	M^3	8.00	600.0	960.0									
O	Laston Surface Coating/Leveler (AC)	Ton	29.00						2100.0	2100.0	2100.0	2100.0	15.6	
P	Laston Layer Foundation/Grader (ATB/L)	Ton	16.00			660.0	231 0.0	2102.2						

The completion of all project activities has a high probability of completion within 274 days. Based on the CPM method, the critical path trajectory is in the sequence of activities M - G - H - N - F - D - E - P - O - K - B - A on the critical path 3. Acceleration of project activities can be done by combining the sequence of activities on

critical path 3 with the optimistic duration on the PERT method.

The acceleration carried out with an optimistic duration on the critical path 3 cut the time from 274 days to 256 days.

4. Conclusion

Based on the analysis that has been carried out using the EVM method, the provider's SPI value in week 26 is 0.75758. The SPI value indicates that the project is experiencing delays. Based on the SPI value in the 26th week, it can be determined that the project completion time with is 242 days. Analysis conducted using the CPM method shows that the critical trajectory is on the path of M - G - H - N - F - D - E - P - O - K - B - A with a duration of activity for 274 days. Calculations made using the PERT method show that the duration that has been calculated by the CPM method has a probability of 71.90%. The acceleration cut the project completion time to 256 days.

References

[1]H. Fahad and E. Endrayadi, "Development of Tourism Sector in Banyuwangi Regency in 2002-2013," *Publika Budaya*, vol. 5, no. 1, pp. 28–35, 2017.

[2]S. Rizky Widyo Kisworo, Fajar Sri Handayani, "Analysis of Project Acceleration Using Time Cost Trade Off Method with the Addition of Overtime Working Hours and Number of Tools," *e-Journal of MATRIX Tek. CIVIL*, vol., no. September 2017, pp. 766–776, 2017, [Online]. Available: https://jurnal.uns.ac.id/matriks/article/view/36702

[3] G. Agus Yudha Prawira Adistana, P. Mahardi, M. Firmansyah Sofianto, and D. Eksana Wibowo, "Accuracy of Prediction of Project Completion Duration with Earn Value Management and Earn Schedule (Case Study of Building Project at Unesa)," *INERTIA lNformation and Expose Has. Ris. Tech. Pill and Arsite.*, Vol. 14, No. 2, pp. 169–179, 2018, DOI: 10.21831/Inertia.V14I2.22539.

[4]T. E. J. Amu, J. Tjakra, and P. A. K. Prastasis, "T e k n o," vol. 21, no. 83, 2023.

[5]A. Senouci, R. M. Leon, and N. Eldin, "Schedule Performance Index Effectiveness in Assessing Project Schedule Performance," Int. J. Constr. Eng. Manag. 2019, Vol. 8, No. 2, pp. 46–55, 2019, DOI: 10.5923/J.IJCEM.20190802.02.

[6]N. Ruseno, "Implementation of Project Construction Cost Management Calculation System Using Web-Based Earn Value Management (EPM) Method," *J. ICT Inf. Commun. Technol.*, Vol. 20, No. 2, pp. 198–201, 2021, DOI: 10.36054/jict-ikmi.v20i2.312.

[7] Fahirah, "Identifying Weaknesses of the Earned Value Method in Measuring Cost and Time Performance of Construction Projects," *Infrastructure*, 2013.

[8] B.-C. Kim and K. F. Reinschmidt, "Combination of Project Cost Forecasts in Earned Value Management," *J. Constr. Eng. Manag.*, Vol. 137, No. 11, pp. 958–966, 2011, DOI: 10.1061/(ASCE)CO.1943-7862.0000352.

[9]S. Ulfa and E. Suhendar, "Implementation of Critical Path Method in Synthesis Residence Kemang Project," *J. Optimization Tech. Ind.*, Vol. 3, No. 1, pp. 1–6, 2021, DOI: 10.30998/joti.v3i1.4167.

[10] Yuli Setiawannie and Nita Marikena, "Planning for Scheduling Preventive Maintenance of Pounch Machine with Critical Path Method at PT. Grafika Nusantara," *INSOLOGY J. Science and Technology.*, Vol. 1, No. 1, pp. 01–10, 2022, DOI: 10.55123/INSTOLOGICAL.V1I1.105.

[11]I. A. Kusumadarma, D. Pratami, I. P. Yasa, and W. Tripiawan, "Developing project schedule in telecommunication projects using critical path method (CPM)," *Int. J. Integr. Eng.*, Vol. 12, No. 3, pp. 60–67, 2020, DOI: 10.30880/ijie.2020.12.03.008.

[12]A. E. Husin, D. I. Rahmawati, M. Meisaroh, and D. Bernadette, "Box Girder Construction on Toll Road Project use Manual Program Evaluation and Review Technique (M-PERT) and Value Engineering (VE) to Performance Cost and Time Improvement," *J. Proj. Manag.*, Vol. 2, No. 3, pp. 54–59, 2020.

[13]Y. Mariana and S. Wijaksono, "Project Evaluation and Review Technique (PERT) Analysis in the renovation project of the Church of St. John the Evangelist, Jakarta," *IOP Conf. Ser. Earth Environ. Sci.*, Vol. 794, No. 1, 2021, DOI: 10.1088/1755-1315/794/1/012188.

[14]H. A. Baits, I. A. Puspita, and A. F. Bay, "Combination of program evaluation and review technique (PERT) and critical path method (CPM) for project schedule development," *Int. J. Integr. Eng.*, Vol. 12, No. 3, pp. 68–75, 2020, DOI: 10.30880/IJIE.2020.12.03.009.

[15]P. Yuliarty, N. S. Novia, and R. Anggraini, "Construction Service Project Scheduling Analysis Using Critical Path Method (CPM), Project Evaluation and Review Technique (PERT)," Int. J. *Innov. Sci. Res. Technol.*, Vol. 6, No. 2, pp. 2019–2022, 2021.

[16]C. Orumie Ukamaka, "Implementation of Project Evaluation and Review Technique (PERT) and Critical Path Method (CPM): A Comparative Study," *Int. J. Ind. Oper. Res.*, Vol. 3, No. 1, 2020, DOI: 10.35840/2633-8947/6504.

[17] A. Ratih, Zakia, and D. P. Sari, "Efforts to Accelerate Completion Time in Road Improvement Projects Using CPM and Pert Methods," *J. Civ. Eng. Student*, vol. 4, no. 1, pp. 85–91, 2022.

[18]H. A. Rani, "Construction Project Management," p. 99, 2016, [Online]. Available: https://www.researchgate.net/publication/316081639_Manajemen_Proyek_Konstruksi

[19]A. Marhaendra and S. Qomariyah, "(Case Study on Eastparc Hotel Yogyakarta Development Project),"

pp. 157–164, 2013.

[20]A. Husamuddin, P. Pusporini, and D. Andesta, "DAMAGE ANALYSIS OF WEIGHBRIDGE UNIT 1 at PT. PETROKIMIA GRESIK USING FAILURE MODE and EFFECT ANALYSIS methods and LOGIC TREE ANALYSIS METHODS," *JUSTI (Journal of Sist. and Tek. Ind.*, Vol. 1, No. 2, p. 118, 2021, DOI: 10.30587/justicb.v1i2.2597.

[21]M. Proaño-narváez, C. Flores-vázquez, P. V. Quiroz, and M. Avila-calle, "Application and Future Projections," 2022.

[22]M. Izeul *et al.*, "Earned Value Method for Cost Performance Analysis of Condotel De Vasa Surabaya Development," *J. Tek. ITS*, vol. 4, no. 1, pp. 54–59, 2015.

[23] PMI, *PMBOK,6th edition*. 2017.

[24]B. Damara, "Cost Performance Analysis and Time Development Construction Project Bridge Chain Karanggeneng Nawacita Cs Using the Earned Value Method," *UKaRsT*, vol. 4, no. 2, p. 177, 2020, doi: 10.30737/ukarst.v4i2.1067.

[25]K. Araszkiewicz and M. Bochenek, "Control of construction projects using the Earned Value Method - case study," *Open Eng.*, Vol. 9, No. 1, pp. 186–195, 2019, DOI: 10.1515/ENG-2019-0020.

[26]I. Meliasari, M. Indrayadi, and Lusiana, "Earned Value Analysis of Cost and Time in Construction Projects (Case Study of Coastal Security Facilities/Infrastructure Development Project)," *J. Tek. Civil Univ. Tanjungpura*, vol. 2, no. 2, pp. 1–11, 2011.

[27]E. W. P. Ramdani, P. Tutuko, H. Budiyanto, and ..., "The role of time and cost control in CPM, PERT, and EVA methods in construction projects: A meta-analysis study on evaluating project performance," *Appl. Eng. ...*, Vol. 1, No. 1, pp. 33–43, 2022, [Online]. Available: https://pubs2.ascee.org/index.php/aet/article/view/668

[28] Andiyan, R. M. Putra, G. D. Rembulan, and H. Tannady, "Construction Project Evaluation Using CPM-Crashing, CPM-PERT and CCPM for Minimize Project Delays," *J. Phys. Conf. Ser.*, Vol. 1933, No. 1, 2021, DOI: 10.1088/1742-6596/1933/1/012096.

[29]A. S. Syamsudin, J. Tistogondo, and D. A. Restuti Wulandari, "Cost and Time Performance Analysis on Controlling Contruction Projects With 'Pert' Method," *Neutron*, vol. 22, no. 2, pp. 99–103, 2023, doi: 10.29138/neutron.v22i2.184.

[30]A. M. Uktolseja, M. Wullur, and M. M. Karuntu, "Evaluation Of Project Implementation Using PERT And CPM Methods (Case Study: Tolango-Paguyaman, Tolango-Bulontio Road Preservat," vol. 6, no. 2, pp. 1079–1090, 2023.