© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie

The International Journal of Integrated Engineering

Combination of Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) for Project Schedule Development

Hamzah Abdul Ba'its*, Ika Arum Puspita, Achmad Fuad Bay

School of Industrial and System Engineering, Telkom University, Bandung, 40257, INDONESIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2020.12.03.009
Received 25 April 2019; Accepted 30 November 2019; Available online 27 February 2020

Abstract: One of the problems faced by the contractors is an inappropriate scheduling method. For project scheduling, the contractor using Bar chart. Although this method still can be used, but in its application is limitedto scheduling large-scale projects, because this method cannot describe the interdependence of activity. The problem can be solved using Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM). PERT is a method that can be used to estimate the duration of activity and can calculate the probability of project time completion, while CPM is a scheduling method used to find the path of critical path and can describe the relationship between activities. Scheduling results using CPM found that the minimum duration to complete the project was 135 days with 20 activities on the critical path with 50% project probability. Further analysis using PERT found that for a greater probability of the project completion was 68% for 139.78 days duration, 95% for 144.56 days, and 99.7% for 149.34 days.

Keywords: Project schedule, bar chart, PERT, CPM, probability

1. Introduction

The project undertaken by the contractor in Cianjur faced many delay problems. Delay in project delivery has been the biggest problem in the construction industry over the year [1]. Because, based on research conducted in 2013, fewer than a third of all the project successfully completed on time globally [2]. There are three leading effect of project delay which are time overrun, cost overrun, and claims that can assist to economic loss for the contractors. Delay causes as seen by project management consultants were cash flow and financial difficulties faced by contractors, contractor's poor site management, inadequate contractor experience, shortage of site workers and ineffective planning and scheduling by contractors [3]. To mitigate this problem, it is required for the contractor to undertake proper project planning [4]. A lot of different technique and tools to assist project manager to create proper planning for the project particularly a project schedule, such as Gantt chart, Critical Path Method, and PERT that have been developed to support an improved project planning [5]. These tools are used widely by a large majority of project managers to identify critical activities and calculate the minimum time required for project completion [5]. Among these methods, the most traditional is Gantt chart and well-known network-based technique of PERT and CPM that widely used to assist project manager in planning and controlling both small and large project an all type of the project including construction, research, development and many others [7].

This research is focus on the construction scheduling of construction of public toilet in Cianjur square. The contractor of this project use bar chart schedule, although this method is valuable tool, its application is limited for scheduling large scale project. Particularly, this method fails to represent the complex relationship among the project activities [8]

*Corresponding author: hamzahabdulbaits@gmail.com

therefore this tool is not giving project team enough information to asses and control project performance while this method only shows the start and end date of the activities. it is proven in some building project in some area such as amphitheater and Kecapi Suling Stage that experience delay of its completion date.

This research will propose PERT and CPM method to make project scheduling in order to improve project schedule performance. CPM is totally different with bar chart scheduling, while bar chart schedule only gives information about start and end date of activity, CPM gives further information which are the start and end date of an activity, the dependency of one activity to another activity, and critical path itself. Critical path method requires forward pass and backward pass to calculate early start, early finish, latest start, and latest finish [9]. In critical path method, the total duration of project can be determined by calculating the critical path which is the longest path in the network diagram. Critical path is the sequence of activity that has zero float, float means the delay time that allowed for an activity without causing delay to overall project [10].

Beside inappropriate method that project team used, there are also uncertainty that may affect the project schedule performance. Since the uncertainty is inevitable for all project [11], required a method that can deal with uncertainty, which is PERT [12]. Starting with a precedence diagram, PERT allows for activity duration estimates to be determined allowing for the uncertainty contained in the duration [13] by using three time estimates (optimistic, most likely, and pessimistic). The three estimates are used to calculate expected time for an activity. The range between the optimistic and pessimistic estimates is a measure of variability that allow to making statistical inference about likelihood that that project events will happen by a particular time [14]. But, in PERT application, there are some advantages that user probably face, especially PERT that using beta distribution, it needed sufficient of historical data to make the estimation more accurate. The differences between PERT and CPM are, PERT is used to estimate activity duration and to analyze the project schedule that developed from CPM, and CPM is used to estimates the minimum project duration and determine the amount of schedule flexibility on the logical network paths within the schedule model.

2. Literature Review

2.1 Related Work

Project Scheduling for Construction Biogas Plant Using Critical Path Method [8]: This paper discusses about the importance of an effective management in the construction of biogas plant since schedule delay may occur in many construction projects. The writer focuses on the scheduling issues that become very important before start of the project. The method that used in this research is network-based procedures of CPM that result 4 critical paths in this project that include the 12 activities from total 15 activities that has duration 38 weeks.

Application of Critical Path Method Scheduling to Research Plan and Management Graduate Student's Research Project in Engineering Education [15]: This research is a useful application of CPM scheduling in managing engineering degree programs with full research exhibited through case study diagnoses. The case study used in this study is an example of a full-time master's degree program in chemical engineering at the University of Witwatersrand, South Africa. In the construction of a project network, activity-on-node (AON) and activity-on-arrow (AOA) are used. The results show that the degree program could be completed in ninety-four (94) weeks instead of the scheduled duration of one-hundred and four (104) weeks, a reduction of 10%. The reduction in the scheduled project duration could avoid unnecessary stress on budget, resources and save energy without jeopardizing the quality of the research output. In the presence of any variability in the activity time of any critical activities, the PERT analysis reveals that the project could still be completed in the scheduled project duration with a probability of 85% without extending the scheduled project duration.

Duration Estimation Method for Highway Construction Work [16]: This research conducted to estimates the duration of highway construction that contain a lot of uncertainties. The writer explains that key factor that must be considered is how the duration will be estimated. How the duration of project work will be estimated can determine the project success or failure. The writer of this project use PERT to addresses uncertainty in the duration. Besides that, the writer uses additional coefficient calculation that inserted to the PERT calculation.

The PERT Method in Estimating Project Duration [17]: In this paper, the writer explains that most of less experienced company do not collect historical information that affecting time limit for project duration and the time duration for specified activities are determine based on estimation and companies own experience. To minimize error arising as a result of using incomplete historical data, the effectiveness of estimating the duration of the project most of project manager use PERT method to estimate the duration of individual tasks of the project on the basis of three-time estimate. Through this study, the writer using PERT into ERP project implementation. There are eight activities with three types of duration that include in this project. The resulted of PERT calculation need 27 days to complete the project with probability 50% and 30 days with probability 94.06%.

Scheduling of House Development Project with CPM and PERT Method for Time Efficiency (Case Study: House Type 36) [18]: This paper explains the application of CPM and PERT to develop the construction of house type 36 to get the optimal time planning in the project work. There are 15 individual activities that has existing completion time 173 days and next will be processed using CPM and PERT to find the optimal duration to complete the project. The writer uses CPM and PERT separately and find that CPM generate 131 days to complete project work and PERT generate 136

days required to complete the project work with probability 74.54% to complete. By using CPM and PERT method company can save up to 42 days to complete project work.

2.2 Critical Path Method

Critical Path Method is used to estimate the minimum project duration that represented by critical path or the sequence of activities with the longest duration. CPM also can determine the amount of schedule flexibility that known as the total float. In order to determine the critical path, five parameters are considered for each activity including the earliest start and finish time, the latest start and finish time, and total float. In order to get those five parameters of CPM there are three calculations must to be done, which are [8]:

Forward Pass, this calculation result is to find the earliest start and earliest finish time of each activity. We start the calculation from activity that has not predecessor and the default earliest start time is 1, to find the earliest finish time of first activity is by add earliest start time with duration the subtract it with 1. Then, for the next activity earliest start is resulting from earliest finish time added by 1, and it calculation also done until the end of activity.

$$ES\,(0) = 1 \quad (1)$$

$$(n) = EF + 1 \quad (2)$$

$$(n) = LF - Duration + 1 \quad (3)$$

Backward Pass, Backward pass calculation follows the procedure similar to the forward pass calculation but different in the result. Backward pass calculation result is to find the latest start time and latest finish time instead of the earliest time. Different with forward pass calculation, backward pass calculation starts form the end of the activity as it named. It starts with the latest finish, the value of earliest finish in the last activity will be the latest finish. After that, we can find the latest finish time by subtracting latest finish with the activity duration and add it by one. After find latest finish and latest start time at zeroth activity, we find the next latest finish by subtracting latest start from zeroth activity with one, it operation implemented for the next latest finish.

$$(end) = EF(end) \quad (4)$$

$$(n) = LS(n) - 1 \quad (5)$$

$$(n) = LF - Duration + 1 \quad (6)$$

Total Float, after forward pass calculation and backward pass calculation are done, it generates several values which include the earliest start time, the earliest finish time, the latest finish time, and the latest start time. It value are used for slack time calculation or total float calculation. Total float is the amount of permitted delay time for each activity in the project. If the activity has total float equal to zero, it means the activity must be done on time or it will be delayed a whole of the project. Float times are calculated as:

$$= LS - ES = LF - EF \quad (7)$$

2.3 Program Evaluation and Review Technique

Program evaluation and review technique is a mode of management science for planning and control of project [19]. The purpose of PERT is to analyze the project network, not to create a schedule [14]. In the application, PERT addresses the uncertainty in the duration by using three time estimates which are optimistic, most likely, and pessimistic. Optimistic time is the minimum time for an activity, the most likely time is the time that would occur most often if the activity were repeated, and pessimistic time is the maximum time for an activity. The three estimates are related in the form of Beta probability distribution with parameters a, and b as the end-points and m as the most frequent value. The beta distribution is used because it is unimodal (has a single peak value) and not necessarily symmetrical, properties that seem desirable for a distribution of activity duration.

Based on beta distribution and three-time estimate, the expected time (te) and the variance of each activity duration are computed using the following formulas:

$$Te = \frac{O+4M+P}{6} \quad (8)$$

$$V = \left(\frac{P-O}{6}\right) \quad (9)$$

Where: Te = Expected time; O = Optimistic time; M = Most likely time, T = Pessimistic time, V= Variance. PERT relies on the central limit theorem and computes the expected project duration as the sum of the expected durations of the critical path activities, while the variance of the project duration is computed as the sum of the variances of the activities on the critical path. This makes it possible to generate statistical estimates for the probability that a project can be finished by a given due date [20]. The estimated time of completion of Te activity is actually the median of

the Beta distribution and represents the 50th percentile and divides the distribution into two parts. Therefore, Te probability of succeeding is equal to the possibility of Te failing that is 50% or in other words, the project completion time is 50% possible equal and there is also a 50% chance not the same as the estimated time [19].

3. Research Model

The model of this research can be seen in Fig. 1. In this research consist of five variables that influence the research output which are activity list, milestone list, schedule management plan, activity attribute, and three time estimate. Activity list includes all activities required on the project and includes activity identifier and scope of work description for each activity in sufficient detail to ensure that project team member understand what work is required to be completed. Milestone is a significant point or event in a project. A milestone list identifies all project milestones and indicates whether the milestone is mandatory, such as those required by contract, or optional, such as those based on historical information. Schedule management plan is component of the project management plan that establishes the criteria and the activities for developing, monitoring, and controlling the schedule. Activity attributes extend the description of the activity by identifying multiple components associated with each activity. The components for each activity evolve overtime. During the initial stages of the project, they include the unique activity identifier, WBS ID, and activity label or name. When completed, they may include activity description, predecessor activities, successor activities, logical relationship, leads and lags.

Three time estimate is required when apply PERT to project schedule, including optimistic duration, most likely duration, and pessimistic duration. The steps required to develop project schedule start from calculate expected time from three time estimate and make the network diagram from each activity by considering activities logical relationship or dependencies. After making the project network diagram and estimate activity duration calculation has been done, then is to make project schedule model using Critical Path Method approach by performing forward pass calculation to find Earliest Start (ES) and Earliest Finish (EF) then do backward pass calculation to search Latest Start (LS) and Latest Finish (LF). After ES, EF, LS, and LF was found the next step is to find the total float that describes the flexibility of the duration of an activity. Once the CPM calculation is finished, then the project schedule can be analyzed by PERT to find the probability of project completion.

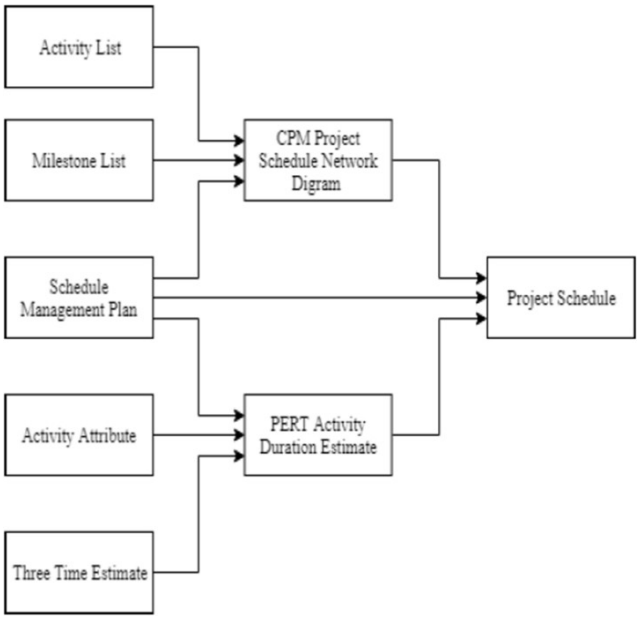

Fig. 1 - Research model

4. Result and Discussion

4.1 Duration Estimation

Project schedule development using PERT technique require three time estimate, which are contains optimistic time which is the minimum duration under the most favorable conditions, most likely duration which are the activity duration that will occur most often, and pessimistic duration which is the activity duration under the least favorable condition. Those three times will be calculated to find expected time using formula Te=(O+4M+P)/6 and the result can be seen in table 1.

Table 1 - Duration estimation

No	Activity	Optimistic	Most Likely	Pessimistic	Expected Time
1	Bowuplank measurement and installation	2	3	4	3
2	Soil excavation work	2	4	5	4
3	Sandfill work	1	2	3	2
4	Aanstamping work	2	7	12	7
5	Tub control work	1	2	3	2
6	River stone foundation work	2	7	12	7
7	Soil levelling work	1	3	5	3
8	Reinforced concrete sloof work	5	8	11	8
9	Reinforced concrete column work	5	11	17	11
10	Dirty water installation	2	5	8	5
11	Red brick wall work	11	15	19	15
12	Reinforced concrete ring balk work	3	5	7	5
13	Plastering work	11	15	19	15
14	Workshop floor work	3	5	7	5
15	Clean water installation	7	11	15	11
16	Lighting installation	2	6	10	6
17	Reinforced concrete dak work	5	8	10	8
18	Gutter work	3	6	8	6
19	Wall renderring work	11	15	19	15
20	Gypsum ceiling work	8	10	12	10
21	Door frame work	2	5	8	5
22	Bouvenlight frame work	3	6	8	5.5
23	Ceramic tile wall work	7	10	12	10
24	List gypsum ceiling work	3	5	6	5
25	Ceramic tile floor work	5	7	8	7
26	Sanitary equipment installation	2	4	5	4
27	Wall painting work	7	10	13	10
28	Ceililng painting work	1	3	4	3
29	Gutter painting work	2	4	6	4
30	Double switch installation	2	5	7	5
31	Downlight LED installation	2	5	7	5
32	Exhaust fan installation	2	5	7	5
33	Cleaning and clearing work	2	5	8	5
34	Commissioning Test	1	2	3	2

4.2 Critical Path Method Analysis

After the duration of each activity has been determined from three time estimate calculation, the next step is calculate the duration of every path on the network diagram to determine which are activity that included in critical path to do further calculation of forward pass and backward pass calculation. The result of Critical Path Method of public toilet construction project can be seen in Table 2. From Table 1 can be seen that there are 20 activities that has total float equal to zero that indicate those activities are critical that has total duration 135 days. From these results can be used as guidance for the project team to give more attention to the activities included in the critical activities as this activity will greatly affect the duration of completion of the project as a whole. If any one or more of the above activities is delayed, it will result in delay of the completion of the project from a predetermined schedule.

The resulted of duration estimate using PERT and schedule model using CPM result duration longer than the existing planning schedule that planned for 84 days. There is huge gap between existing schedule and the schedule developed by PERT and CPM. Writer found that the activity duration estimate of the existing planned schedule is not accurate and not effective since there is some delay in other project in same area such as Amphitheater that should be finished on 12th May and delayed for 47 days and it still ongoing progress. There's also Kecapi Suling Stage that planned finish on 26th may and delayed for 34 days and it still ongoing progress. The other reason of the huge gap between the existing planning and PERT and CPM scheduling is because the existing schedule unlike PERT, is not insert the risk factor to the duration estimate.

4.3 PERT Analysis

The total duration of the project has been determined through the calculation of CPM, as shown in table II. It is known that there are 20 series of activities that form a critical path. From the result on critical activity, only representing

50% of project probability will be solved, since the estimated time at PERT interest is the median of beta distribution. Or, in other words, the public toilets construction project in Cianjur city square has a 50% probability of project duration 135 days to complete.

To find the probability of a larger project completion, further calculations can be made by finding the variance of activity on the critical path which will then be searched for standard deviation for the entire duration of the project. To find the variance of the critical activity using the formula $\sigma = ((P-O)/6)$. The result of variance calculation from the activity of critical path showed in Table 3.

Table 2 - CPM Result

No	Activity	Duration	ES	EF	LS	LF	Total Float
1	Bowplank measurement and installation	3	1	3	1	3	0
2	Soil excavation work	4	4	7	4	7	0
3	Sandfill work	2	8	9	8	9	0
4	Aanstamping work	7	10	16	10	16	0
5	Tub control work	2	10	11	127	128	117
6	River stone foundation work	7	17	23	17	23	0
7	Soil levelling work	3	24	26	24	26	0
8	Reinforced concrete sloof work	8	27	34	27	34	0
9	Reinforced concrete column work	11	35	45	35	45	0
10	Dirty water installation	5	35	39	124	128	89
11	Red brick wall work	15	46	60	46	60	0
12	Reinforced concrete ring balk work	5	61	65	61	65	0
13	Plastering work	15	74	88	74	88	0
14	Workshop floor work	5	61	65	113	117	52
15	Clean water installation	11	61	71	118	128	57
16	Lighting installation	6	61	66	123	128	62
17	Reinforced concrete dak work	8	66	73	66	73	0
18	Gutter work	6	74	79	119	124	45
19	Wall renderring work	15	89	103	89	103	0
20	Gypsum ceiling work	10	74	83	111	120	37
21	Door frame work	5	104	108	109	113	5
22	Bouvenlight frame work	6	104	109	108	113	4
23	Ceramic tile wall work	10	104	113	104	113	0
24	List gypsum ceiling work	5	84	88	121	125	37
25	Ceramic tile floor work	7	66	72	118	124	52
26	Sanitary equipment installation	4	73	76	125	128	52
27	Wall painting work	10	114	123	114	123	0
28	Ceililng painting work	3	89	91	126	128	37
29	Gutter painting work	4	80	83	125	128	45
30	Double switch installation	5	124	128	124	128	0
31	Downlight LED installation	5	124	128	124	128	0
32	Exhaust fan installation	5	124	128	124	128	0
33	Cleaning and clearing work	5	129	133	129	133	0
34	Commissioning Test	2	134	135	134	135	0

After calculating the total variance of the activity on the critical path, the next step is to find standard deviation by rooting the total variance, so it is known that the standard deviation is 4.78. The next step after knowing the standard deviation of the activity on the critical path is to do the calculation with the three-sigma rule of thumb that has three confidence levels of 68%, 95%, and 99.7%, of which each confidence level in the three-sigma rule of thumb representing 1 sigma, 2 sigma, and 3 sigma, and calculation to find probability of project completion can be done with following formula:

- $\mu+\sigma$ for 1 sigma
- $\mu+2\sigma$ for 2 sigma
- $\mu+3\sigma$ for 3 sigma

So the total duration required to complete the project with probabilities of 68%, 95%, and 97% respectively is as follows:

- 135+4.73=139.78 for probability 68%
- 135+2(4.73) =144.56 for probability 95%
- 135+3(4.73) =149.34 for probability 99.7%

Or in other words, there is a 50% probability of the project to be completed within 135, there is 68% probability of the project to be completed within 139.78 days, there is 95% probability the project will be completed within 144.56 days, and there will be 99.7% project will be completed in time 149.34 day.

Table 3 - Variance of activity

No	Activity on Critical Path	Pessimistic	Optimistic	Variance [(P-O)/6]
1	Boowplank measurement and installation	4	2	0.11
2	Soil excavation work	5	2	0.25
3	Sandfill work	3	1	0.11
4	Aanstamping work	12	2	2.78
5	River stone foundation work	12	2	2.78
6	Soil levelling work	5	1	0.44
7	Reinforced concrete sloof work	11	5	1.00
8	Reinforced concrete column work	17	5	4.00
9	Red brick wall work	19	11	1.78
10	Reinforced concrete ring balk	7	3	0.44
11	Plastering work	19	11	1.78
12	Reinforced concrete dak work	10	5	0.69
13	Wall rendering work	19	11	1.78
14	Ceramic tile wall work	12	7	0.69
15	Wall painting work	13	7	1.00
16	Double switch installation	7	2	0.69
17	Downlight LED installation	7	2	0.69
18	Exhaust fan installation	7	2	0.69
19	Cleaning and clearing work	8	2	1.00
20	Commissioning Test	3	1	0.11
			Total	22.83

4.4 Alternative Schedule Analysis

Creating alternative schedule is important for every project it can give the other option of project schedule for project team. In this research, alternative schedule is made based on default project schedule that obtain from CPM calculation. This research will create alternative schedule using fast tracking method. When do fast tracking, we review the dependency among the activity that can be re- customized, the activity in critical path that can be re- sequenced is that activity that has discretionary dependency or soft logic and also review the possibility to apply lead by overlap the successor activity with its predecessor. But, by applying fast tracking may cause increase risk and cost [21]. Based on the type of the dependency and lead consideration, there are some changes to the dependency. There are four activities that feasible to be applied leads which are Soil levelling work, reinforced concrete sloof work, reinforced concrete column work, and wall rendering work. Form the application of schedule fast tracking it can reduce the total duration to 117 days. Proper project scheduling can make proper budget planning. The significant causes of budget overrun were improper planning, variation in materials price, poor site management, lack of communication between parties, frequent design changes, incompetent contractors, mistakes during construction, shortage of site workers, delay in material procurement, and low speed of decisions making [22].

Dependency of activity 9 (reinforced concrete column work) is changed and can be done after the soil levelling work finished, since the dependency of activity 11 (red brick wall work) also changed become the successor of activity 8 and 9 and can be done after activity 9 finished since activity 9 has longer duration than activity 8. But, to apply this in this activity will increase rework probability if this activity is not managed properly since these activities use same resource. Beside change activity dependency, effort can be done is apply leads to activity 7 (Soil levelling work) and activity 19 (Wall rendering work). Activity 7 can be lead respect to activity 6 by three days so generate 6FS-3 days dependency, since activity 6 (River stone foundation work) is being done per are of the project, and it not necessary to activity 7 to wait activity 6 until it finished and can be done after activity 6 is being done in certain area of the project. The next activity that has new dependency is activity 19 (Wall rendering work) that become 13FS-7 days. It means, that activity 19 can be done seven days before activity 13 (Plastering work) finished. The consideration of applying lags to activity 19 is that the activity 13 is done per area of the wall, and activity 19 can worked over area that the plastering work has be done.

5. Summary

Duration of time required to complete the project as a whole is 135 days that obtained from critical path method calculation. The total duration of 135 days to complete the project is obtained from the sequence of 20 activities in critical path. These activities need more attention from project team because if any one or more activity in critical path is delayed, it will result in delay of the completion of the project from a predetermined schedule. The further analysis of project schedule using PERT result probability to complete the project within 135 days is 50% because the estimated time at PERT estimation is the median of beta distribution. The PERT method also can use the approach of sigma to look for the other probability. There are 68% probability to complete project within 139.78 days, 95% probability to complete project within 144.56 days, and 99.7% probability to complete project within 149.34 days. This research is also providing alternative schedule by applying fast tracking to the project schedule based on CPM calculation result. The application of fast tracking can reduce the project duration up to 17 days become 117 days. But, using fast tracking in case of schedule fast tracking usually increases coordination efforts between the activities concerned and increase quality risk.

Acknowledgement

The authors would like to acknowledge the Telkom University, Bandung.

References

[1] Pawanhari, Panday, M. & Rakesh, G., (2016). Effect of Time Delay in Construction Projects. International Journal of Engineering Development and Research, 4(2).
[2] Standish (2013). Chaos Manifesto 2013, Boston: The standish Group International.
[3] M. Abdullah, A. Abdul Azis, and I. Abdul Rahman, (2009). Potential Effects on Large Mara Construction Projects Due To Construction Delay. International Journal of Integrated Engineering (IJIE), vol. 1, no. 2, 1.
[4] Ojoko, E., Tanko, B. & Enegbuma, W., (2016). Project Delay Cause and Effects in the Construction Industry. International Graduate Conference on Engineering, Science and Humanities
[5] Yang, J.-B., (2007). How the Critical Chain Scheduling Method is working for Construction. Cost Engineering, 49(4), 25-32.
[6] Fahimifard, S. & Kehkha, A., (2009). Application of Project Scheduling in Agriculture (Case Study: Grape Garden Stabilization). Journal Agriculture & Environment, 5(3), 313-321.
[7] Hillier, F. S. & Lieberman, G. J., (2005). Project Management with PERT/CPM. In: Introduction to Operational Research. 8th ed. Boston: McGraw Hill.
[8] Zareei, S., (2018). Project Scheduling for Constructing Biogas Plant Using Critical Path Method. Renewable and Sustainable Energy Review, 12, 756- 759.
[9] Lu, M. & Hoi-Cing, L., (2008). Critical Path Scheduling under Resource Calendar Constraint. Journal of Construction Engineering and Management, 134, 25-31.
[10] Khodakarami, V., Fenton, N. & Neil, M., 2007. Project scheduling: improved approach to incorporate uncertainty using Bayesian networks. Project Management Journal, 38(2), pp. 39-49.
[11] PMI (2009). Practice Standard for Project Risk Management. 2nd ed. Pennsylvenia: Project Management Institute.
[12] Jun-Yan, L., (2012). Schedule Uncertainty Control: A Literature review. Physics Procedia, 33, 1842-1848.
[13] PMI (2011). Practice Standard for Scheduling. 2nd ed. Pennsylvania: Project Management Institute, Inc.
[14] Nicholas, J. M. & Herman, S., (2012). Project Management for Engineering, Business and Technology. 4th ed. New York: Routledge.
[15] Daromala, M., (2014). Application of Critical Path Method Scheduling to research plan and management of graduate student's research project in engineering education. Johannesburg, QScience.
[16] Weijun, L., (2011). Duration Estimation Method for Highway Construction Work. Wuhan, IEEE.
[17] Nafkha, R., (2016). The PERT Method in Estimating Project Duration. Information System in Management, 5(4), 542-550.
[18] Kholil, M., Alfa, B. N. & Hariadi, M., (2010). Scheduling of House Development Project with CPM and PERT Method for Time Efficiency (Case Study: House Type 36). s.l., IOP.
[19] Siswanto (2007). Operations Reseach. 2nd ed. Jakarta: Erlangga.
[20] Demeulemeester, E. & Harroelen, W., (2011). Robust Project Scheduling. Foundation and Trends in Technology, Information, and Operations Management, 3, 201-376.
[21] Dehghan, R. & Runwapura, J., (2011). The Mechanism of Design Activity Overlapping in Construction Project and the Time-Cost Tradeoff Function. Procedia Engineering, 14, 1959- 1965.
[22] K. Ullah, A. H. Abdullah, S. Nagapan, S. Sohu, and M. S. Khan, (2019). Measures to Mitigate Causative Factors of Budget Overrun in Malaysian Building Projects, International Journal of Integrated Engineering (IJIE), vol. 10, no. 9.