M-PERT and Line of Balance (LoB) Integration on Earthwork in Industrial Estates

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Abstract: In a construction project, the planning and scheduling stages determine the success of the project. Project scheduling is an activity in compiling sequences of activities and duration that include information about costs, materials, labor, methods, work tools and progress of work completion. In this study using the M-PERT method (Manual Evaluation Review Technique Program) and LoB on earthwork projects. PERT method by creating a network planning diagram through the Activity on Arrow (AOA) approach so that the sequence of activities can be known. While the LoB method by simplifying the stages of activities which are then made a line diagram, this is to facilitate the analysis of conflict. The processing of statistical data uses SPSS edition 25 which will get the equation model. The time of the earthwork project in accordance with the plan is 77 days, after applying the Line of Balance (LoB) method up to 65 days, resulting in a time efficiency of 15.6%. Based on the weekly progress report the realization of earthwork work is for 74 calendar days. Based on the calculation of scheduling using M-PERT according to the picture above, the results show that the total time needed for 72.55 days resulted in a 1,99% error.

Keywords: M-PERT, line of balance, earthwork, time optimization

1. INTRODUCTION

Construction projects can be defined as a temporary activity with the aim of building facilities and infrastructure that are done with a limited period of time, allocation of certain funding sources, and intended to achieve the tasks and targets outlined.

The success of a construction project is very dependent on the planning and scheduling stages. Project scheduling helps show the relationship between activities in a project, identifies relationships that must take precedence between jobs, and shows realistic time estimates for each work item. Timeliness of completion is one aspect of evaluating the success of the project.

Therefore, through good planning, it is expected that the project can be completed according to the specified time target, with the use of efficient costs, and the quality of work as expected. For this reason, many methods have been developed to schedule project implementation times, including Chart Bars and curves S, CPM (Critical Path Method), PDM (Precedence Diagram Method), PERT Balance) etc.

2. LITERATURE REVIEW

2.1. Project Scheduling

Scheduling in terms of construction projects is a device to determine the activities needed to complete a project in a certain sequence and software in JPG, PNG or TIFF formats or vector drawings made in packages like Adobe Illustrator, CorelDraw, Inkscape, Matlab etc. and saved in EPS or PDF format. Please do not create line drawings with the built-in features of Microsoft Word as we shall need these drawings in separate files in the final version.

Historical data from 1995 to 2001 stated that there were 1722 cases of project duration delay, averaging 11.95% of the initially stated duration. The average delay time was 59 days from the initial duration of 494 days [1]. An earlier study done by Levin and Kirkpatrick (1972), stated that the Critical Path Method (CPM) is a method to plan and supervise a project. This system is mostly used on a network-based project. The utilization of CPM will clarify the amount of time needed to complete various phases of the project along with the relationship between every used source and the time needed to complete the project. [2].

The CPM (Critical Path Method) theory using AON to make it easier to create and analyze critical paths. This theory was developed by giant company Dupont. Although the name differs from PERT, in principle, PERT is in line with CPM [3]. In late 1956, a team at Du Pont under Morgan R. Walker was tasked with developing a system for planning, scheduling, and controlling, complex engineering projects [4]. Program (or project) evaluation review technique (PERT) has remained a modern method in the project schedule for decades. Since its invention, numerous authors have tried modifications to its basic method in an attempt to overcome its intrinsic drawbacks [5]. A new path float concept was presented differently from that of traditional CPM. An example network was used to compare the path float and its use rate using two methods to calculate the path float. Some conclusions and problems concerning the path float use are discussed as follows. [6]

2.2. M-PERT Method

M-PERT is a project scheduling method which is a continuation of the PERT method invented by Pablo Ballesteros Perez in 2017. The M-PERT method can increase the accuracy of project scheduling with a 1% error rate while the PERT method with an error rate of 10% [7]. The PERT technique is a method that aims to reduce as much as possible the delay and disruption of production and coordinate various parts of a project as a whole and accelerate the completion of the project. [8]

The PERT method not only allows users to calculate the duration of the project that is most likely to occur, but also allows users to calculate the probability (probability) of the project or part of the project that will be completed within a certain period of time. PERT has six basic steps as follows:

- Define the project and prepare a fractional work structure.
- Build relationships between activities. Decide which activities must be done first and which ones must follow the others.
- Describes the network that connects the whole activity.
- Determine the estimated time and/or costs for each activity.
- Calculates the longest time path through a network. This is called the critical path. [9]

In the PERT network sets three estimates of time (three times estimates) for each network of activities. Three times estimates include: [10]

- Optimistic time (to time) (to): is the shortest time that an event might occur. The time needed for an activity if everything goes according to plan. In estimating values, there is usually a small chance (say 1/100) that the activity period will be <to.
- Pessimistic time (tp): is the longest time the event is needed. The time needed for an activity assuming the conditions are very unexpected. In estimating this value, there is usually also an (also, 1/100) that the activity time will be> tp.
- Most probable times (tm): the most appropriate time to complete activities in a PERT network, is the time most often occurs if an activity is repeated several times.

The formula for determining the expected time is:

$$te = \frac{to + 4tm + tp}{6} \qquad (1)$$

Based on formula above, the value of expected time (te) is influenced by the optimistic time (to) value, pessimistic time (tp) and most probable time (tm). The higher value of to, tp and tm, the higher value of te and vice versa.

One of the alternatives on the project scheduling is called Manual Project-Duration Estimation Techniques (M-PERT) which is the further development/version of The Program Evaluation and Review Technique (PERT). M-PERT is a similar scheduling method to PERT, but M-PERT uses activity-on-node (AON) which focus on the finish-start relationship, and this method resulted from an array of project scheduling showing total duration of construction work by combining and merging two or more active process. [11]

2.3. Line of Balance (LoB) Method

The line of balance (LoB) method is a method of scheduling projects that are generally used for projects that have repetitive activities [12]. The LoB method can optimize the duration of work execution up to 50% [13] and can increase the efficiency of implementation time by 20% [14]. The LoB method can display the repetitive work schedule of each unit in the form of a line diagram. The process of scheduling using the LoB method involves the following basic steps [15]

- Prepare a logic diagram that shows the sequence of production one cycle of repetitive work
- Estimating the number of work teams for each activity
- Prepare a LoB schedule
- Determine the buffer time (if desired)
- Draw the LoB chart
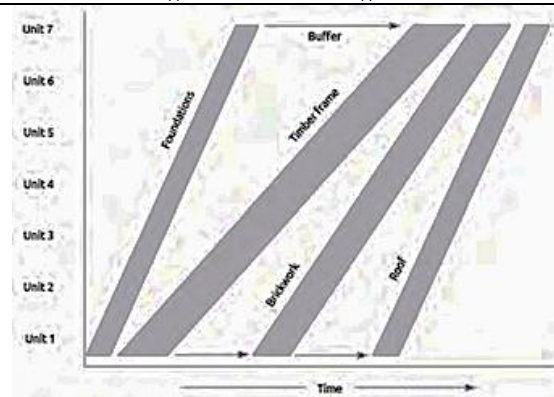
Source: Ammar, 2001 [15]

In figure 1 above is one example of the application of line diagrams in LoB on repetitive work.

2.4. Earthwork

The discrete simulation model is applied to simulate earthmoving operations and generate schedules for dispatching various trucks, and the GAs are used as a filter to screen out schedules that require long trips [17] The optimization aims at minimizing time and cost of earthmoving operations. The proposed framework considers factors that influence earthmoving operations including equipment availability and project indirect cost. The simulation process, in the proposed methodology, utilizes discrete event simulation and object-oriented modeling [18]

Large scale earthmoving operations require the use of heavy and costly construction equipment. Optimum utilization of equipment is a crucial task for the project management team. It can result in substantial savings in both time and cost of earthmoving operations [19]. According to Mohd. SaidinMisnan (2002) from the University of Technology Malaysia, that the definition of earthwork is the process by which the earth's surface is dug and transported to and compacted in other locations [20].

Productivity and Duration of Job

In determining the duration of a job, the things that need to be known are the work volume and productivity of the tool. Tool productivity depends on the capacity and cycle time of the tool. The basis for searching.

The Productivity of tools is:

$$Productivity = \frac{Equipment\ \ capacity}{CM} \qquad (2)$$

Based on formula (2) above, the productivity of heavy equipment is influenced by tools capacity and time cycle. The higher tools capacity and lower time cycle, then the productivity will be higher.
To obtain a cycle time (CM) is needed as the following:

$$CM = TL + TH + TD + TR + TW \qquad (3)$$

Where:
C_m = cycle time (seconds)
TL = playback time (seconds)
TH = transport time (seconds)
TD = time to shed (seconds)
TR = back time (seconds)
TW = waiting time (seconds)
Based on formula (3) above, the value of cycle time is influenced directly by the value of playback time, transport time, time to shed, back time and waiting time. The higher value of time, the higher cycle value.And vice versa.
Whereas for calculating the number of other tools use the formula as follows:

Number of tools= (Highest Productivity)/(Tools Productivity)   (4)

Based on formula number (4) the amount of heavy equipment is influenced directly by the highest production value and tools productivity. The higher production value and the lower tools productivity value then the amount of heavy equipment will be greater, and vice versa.

After the number of each tool is known, then it is necessary to calculate the duration of the work of these tools. One way is to determine the total productivity of the tool after multiplying the amount. Then by using the productivity of the number of tools, the duration can be searched using the following formula:

$$\text{Duration} = \frac{\text{Work Volume}}{\text{Lowest Productivity}} \qquad (5)$$

Based on formula number (5) above, the work duration is directly influenced by the value of working volume and the smallest productivity of heavy equipment. The higher the working volume and the lower the smallest productivity then the duration will be higher, and vice versa.

The earthwork project done in the study is zone G1 in industrial area Krakatau II CilegonBanten Indonesia, with the contour and planning picture of G1 as below :
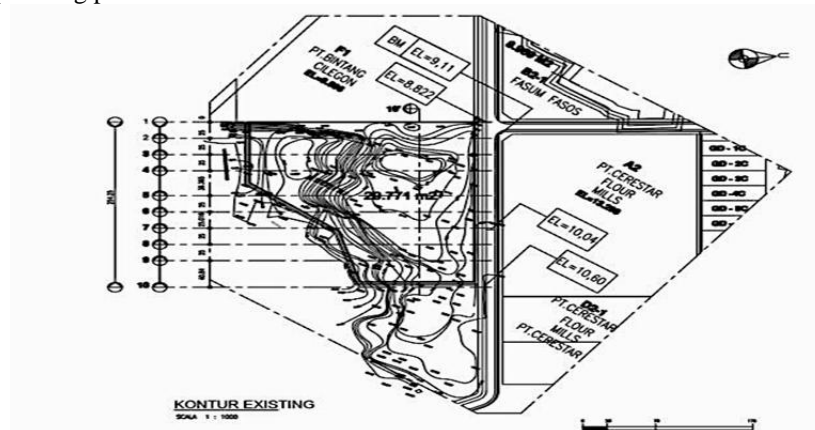

Fig. 1. Existing plot G1 contour

3. RESAERCH METHODOLOGY

In this study using two data, namely primary data obtained from interviews with contractors and direct observation in the field, while for secondary data obtained from data in the field in the form of time schedules, working drawings, RAB and BOQ. The overall methodology research flow chart is divided into three stages, namely the preparation stage, the stages of the research method and the stages of application in accordance with figure 2 below:
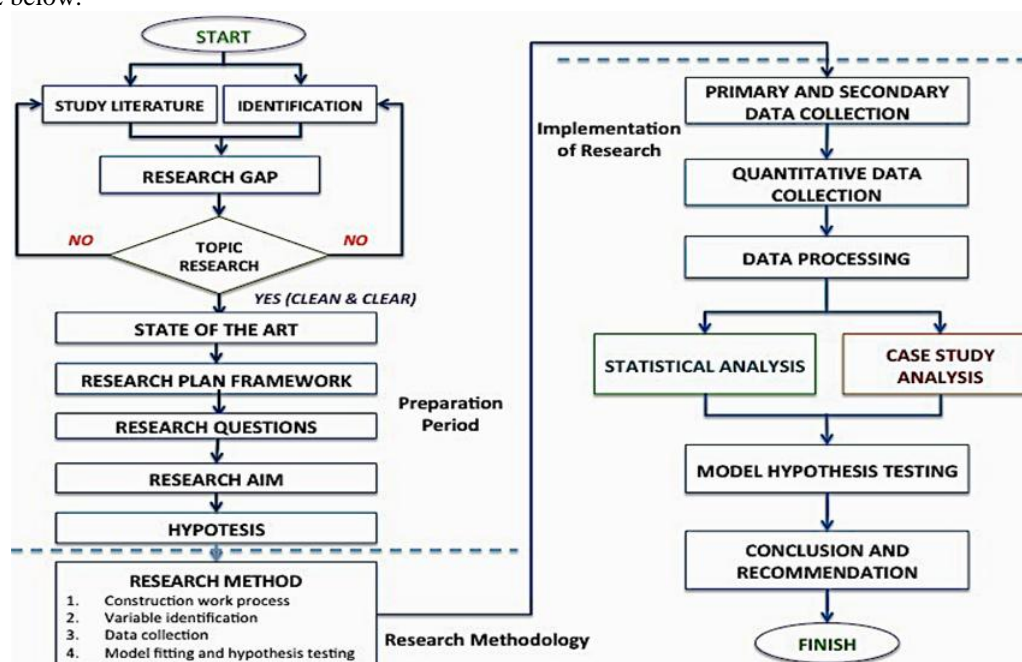

Fig. 2. Flowchart Reasecrh Methodology

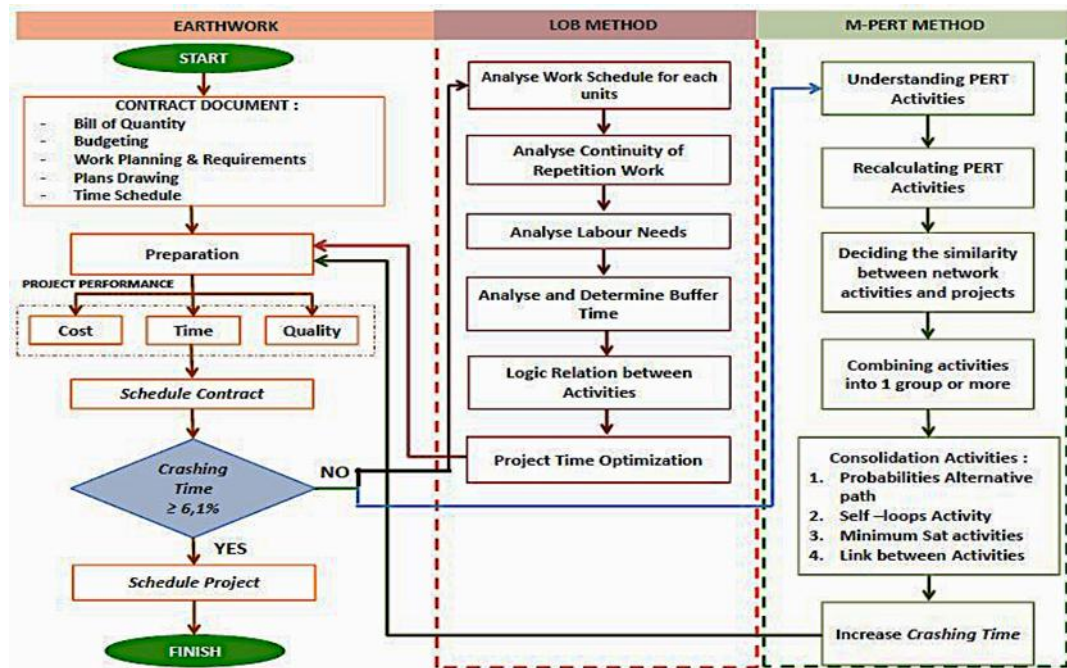The application of the M-PERT and LoB scheduling method on earthwork projects according to figure 3. below:

Fig. 3. Implementation of M-PERT and LoB Method

4. DATA PROCESSING

In this study, the processing of statistical data using SPSS 25 with the number of respondents 36 originating from the distribution of questionnaires consisting of Project Managers, Site Managers, Engineering, Supervisors and Surveyors came from contractors who had worked on earthwork work. The number of main variables is 4 factors and sub-variables are 39 factors. Stages of processing statistical data using SPSS 25 according to the flowchart to figure 4 below:
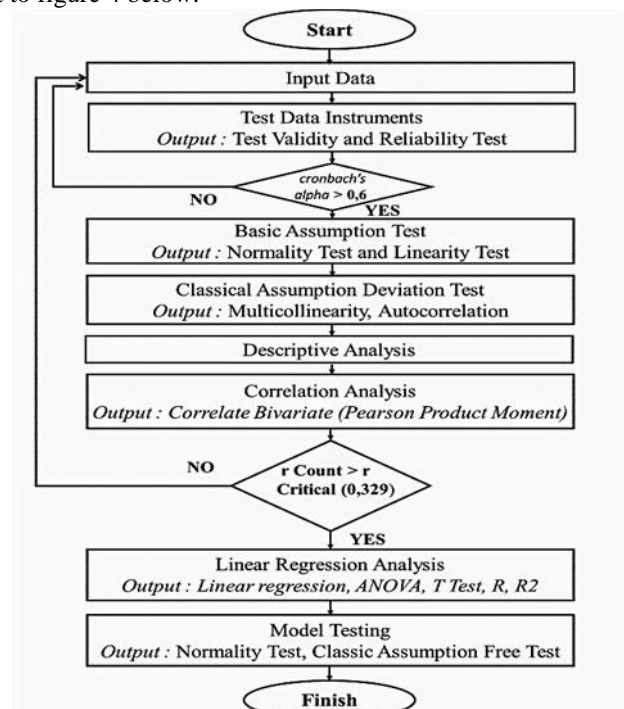

Fig. 4. SPSS 25 Flow Chart

4.1. Reliability Test

Based on the results of statistical analysis using SPSS 25 obtained by Cronbach's Alpha> 0.6 so that all the questions are consistent according to Table 1, 2 and table 3 below

Table 1. Variable Reliability Test X1

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.974	.972	19

Source: SPSS 25 Data Processing

Table 2. Variable Reliability Test X2

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.961	.960	7

Source: SPSS 25 Data Processing

Table 3. Variable Reliability Test X3

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.915	.899	9

Source: SPSS 25 Data Processing

4.2. Validity test

Based on the results of statistical analysis using SPSS 25, the results of r count> r table are obtained so that all valid questions are in accordance with table 4, 5, 6 and Table 7 below:

Table 4. Y-X1 Correlation

Correlations

			X1	
X1	Pearson Correlation	1	.873**	
	Sig. (2-tailed)			.000
	N		36	36
Y	Pearson Correlation	.873**	1	
	Sig. (2-tailed)		.000	
	N		36	36

Source: SPSS 25 Data Processing

Table 5. Correlation between Y and X2

Correlations

		Y	X3
Y	Pearson Correlation	1	.982**
	Sig. (2-tailed)		.000
	N	36	36
X3	Pearson Correlation	.982**	1
	Sig. (2-tailed)	.000	
	N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).
Source: SPSS 25 Data Processing

Table 7. Correlation between Y and X1, X2, X3

Correlations

		X1	X2	X3	Y
X1	Pearson Correlation	1	.987**	.912**	.873**
	Sig. (2-tailed)		.000	.000	.000
	N	36	36	36	36
X2	Pearson Correlation	.987**	1	.890**	.842**
	Sig. (2-tailed)	.000		.000	.000
	N	36	36	36	36
X3	Pearson Correlation	.912**	.890**	1	.982**
	Sig. (2-tailed)	.000	.000		.000
	N	36	36	36	36
Y	Pearson Correlation	.873**	.842**	.982**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	36	36	36	36

**. Correlation is significant at the 0.01 level (2-tailed).
Source: SPSS 25 Data Processing

Person range is -1< Person < 1. Pearson provides a reference if the correlation value is closer to number one, meaning the relationship is getting stronger [20]. After processing statistical data using SPSS 25, multiple linear regression models are obtained as follows:

$$Y = -2{,}899 + 0{,}56 X1 - 0{,}209X2 + 0{,}552X3 \qquad (6)$$

Note:

Y   = Time

X1 =PERT and M-PERT methods

X2 = The LoB method

X3 = Earthwork Work

4.3. Line of Balance (LoB) Method
       The G1 plots maturation project is 5,268 hectares located in the area of Krakatau II Industrial Area, CiwandanCilegonBanten. Based on the project's time schedule, the implementation time is 77 calendar days.

In this study, the author will conduct research on earthwork work applied to the Land Maturation work in the Industrial Estate area with a planned duration of 70 days and only repetitive work can be scheduled with the LoB method, in this case, the work items are:

1. Survey and measurement

2. Mobilization and demobilization

3. Land clearing, stripping, and disposal

4. Excavation, relief and leveling work

5. Cliff cliff work

6. Final compaction (top level)

7. AASHTO 95% standard density test

In the initial planning for earthwork / total earthwork duration is 77 calendar days, this can be seen in table 8 below:

Table 8. Job Duration Planning

No	Activity	Duration/ Cycle(day)	Total Duration	Start Package	Finish Package
1	Survey & Measurement	4	4	0	4
2	Mob & Demob	3	3	4	7
3	Land Clearing, Stripping & disposal	7	28	7	35
4	Excavation, relief &leveling work.	7	70	7	77
5	Cliff cliff work	7	28	49	77
6	Final compaction	7	56	21	7
7	Density Test	7	42	35	77

Before making a LoB diagram, a logic dependency relationship is created from the activity package. The network diagram of the G1 parcel maturation package is as follows :
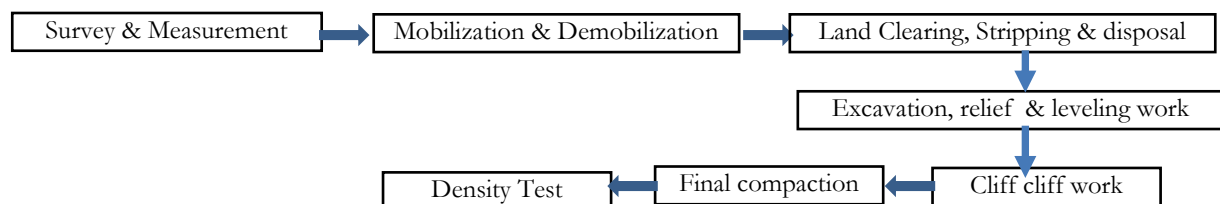
Fig. 5. The logical relationship of LoB dependence

Based on table 8 of the initial LoB Schedule, a line diagram is then made.
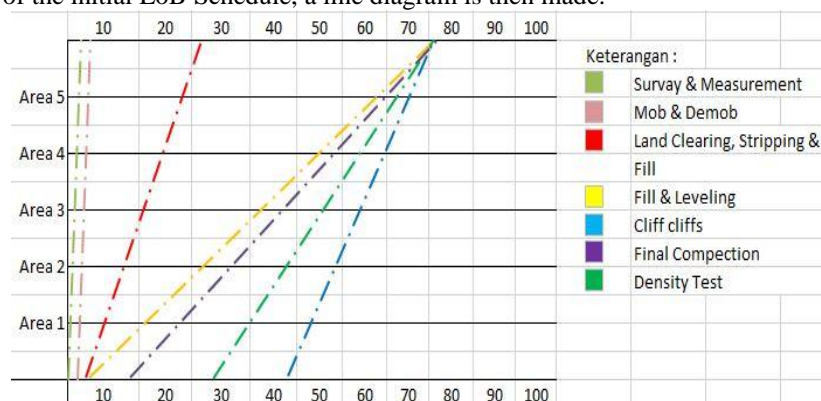
Fig. 6. Initial LoB diagram

From figure 7 above there are no jobs that collide with each other or there is a conflict between jobs but there is a buffer time or waiting time that is long enough so that it needs to be improved on the duration in order to get more efficient and effective duration results.

In this study the researchers will make improvements by minimizing the buffer time at excavation, recovery and leveling work with reduced 1 days from normal duration so that the LoB schedule table is obtained by reducing the buffer time as table 9 below:

Table 9. Schedule LoB by reducing buffer time

No	Activities	Duration per Job Cycle (day)	Total Duration (5,276 Ha)	Start Package (day)	Finish Package (day)
1	Survey & Measurement	4	4	0	4
2	Mob & Demob	3	3	4	7
3	Land Clearing, Stripping & disposal	5	28	7	28
4	Excavation, relief &leveling work.	14-1 =13	65	7	65
5	Cliff cliff work	5	28	37	65
6	Final compaction	11	56	9	65
7	Density Test	8	42	23	65

Based on calculations in table figure7 above, the author tries to estimate the time of completion in excavation, maintenance and leveling work with reduced 1 so that it becomes 13 days. From the calculation of the reduction in duration, the total duration will be 65 days.
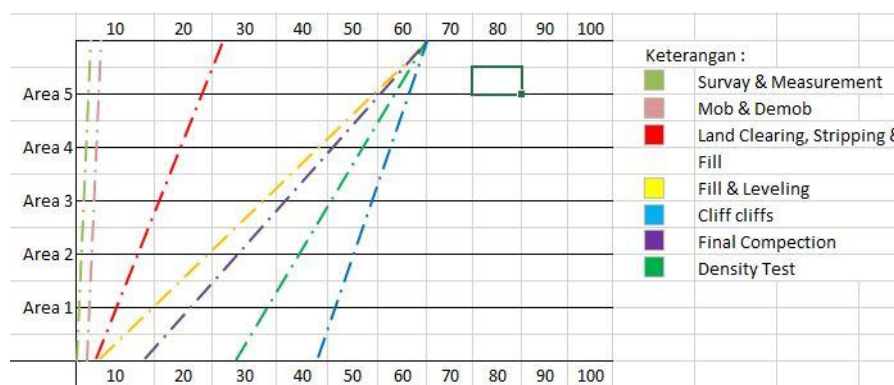
Fig. 7.LoB Diagram reduced 1 day

From the results of the application of Line of Balance scheduling that has been done, we can make a logic thinking from the line of balance scheduling method, namely:

In the application of Line of Balance, there must be no work that collides with each other or conflicts with each other. The work of successors may not be completed before the predecessor's work is finished.

If the duration of one successor's work cycle is less than the duration of one cycle of predecessor work, then the successor's work must start from the finish of the predecessor work package plus the duration of one successor work cycle.

If the duration of a successor's work cycle is greater than or equal to the duration of the work of a predecessor cycle, then the successor's work can start from the predecessor work package plus the duration of one cycle of predecessor work.

4.4. CPM Scheduling
Based on the CPM Scheduling method, the figure of critical network planning from earthwork in an industrial estate is pictured as figure 8 below
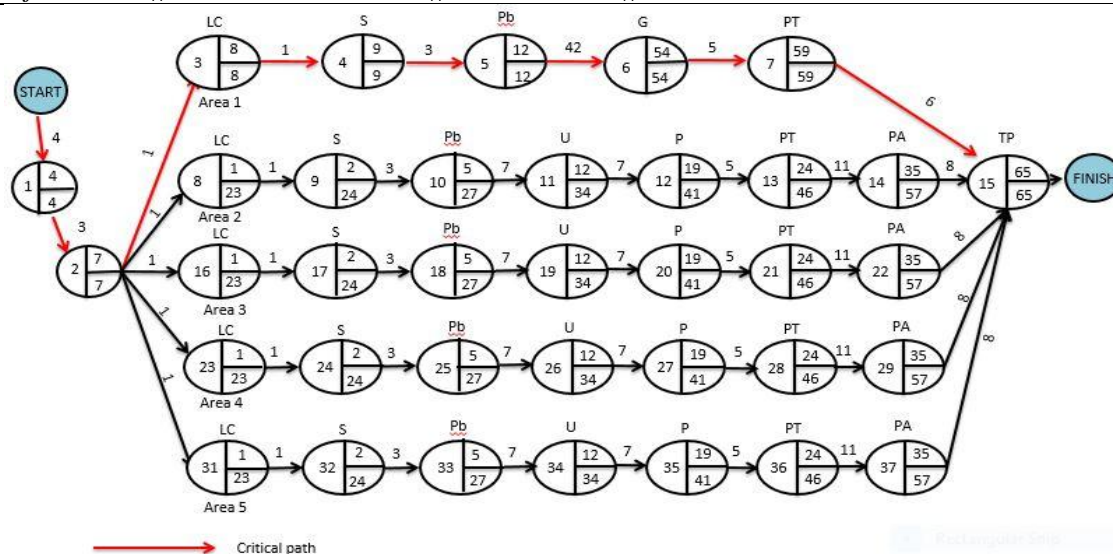
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Fig. 8. The Critical path to earthwork project

4.5. PERT scheduling result

The calculation of schedule using the PERT method through 3 stages :
Stage 1 is calculating expected time using the formula below :

$$te = \frac{to + 4tm + tp}{6} \qquad (6)$$

Whereas:
te = expected duration ; to = optimistic duration ; tm = moderate duration ; tp = pessimistic duration
Stage 2 is calculating the variance value of each activity, with the formula as follows:

$$V = [(tp-to)/6]^2 \qquad (7)$$

Whereas :
V = variance ; tp = pessimistic duration ; to = optimistic duration
Stage 3 is calculating the value of the project variance in the critical path with the formula as follows:

$$\sigma_p = \sqrt{\Sigma v} \qquad (8)$$

Whereas:
σp = project standard variance ; Σvp = critical path total variance

4.6. M-PERT scheduling result

The calculation formula uses the M-PERT method in calculating the series according to figure 9 and parallel according to figure 11 below:
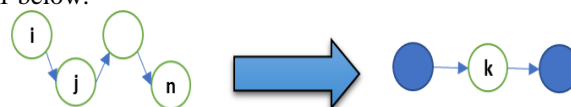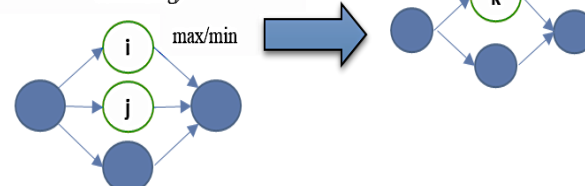

Fig. 9. Series combination on M-PERT

Fig. 10. The Parallel combination of M-PERT

The calculation using the M-PERT method is a continuation of the calculation using the LoB and PERT methods below:
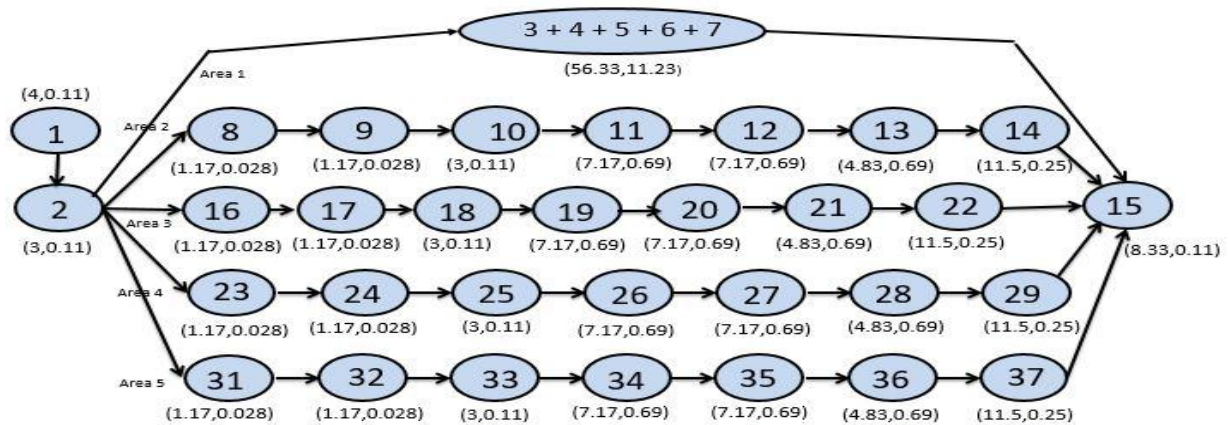
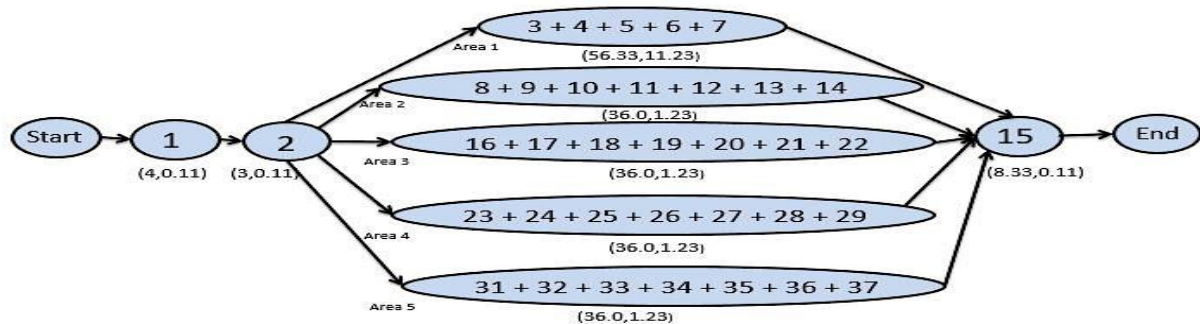The stages of applying the M-PERT method are as below:

Fig. 11. Step 1, 5 mergers
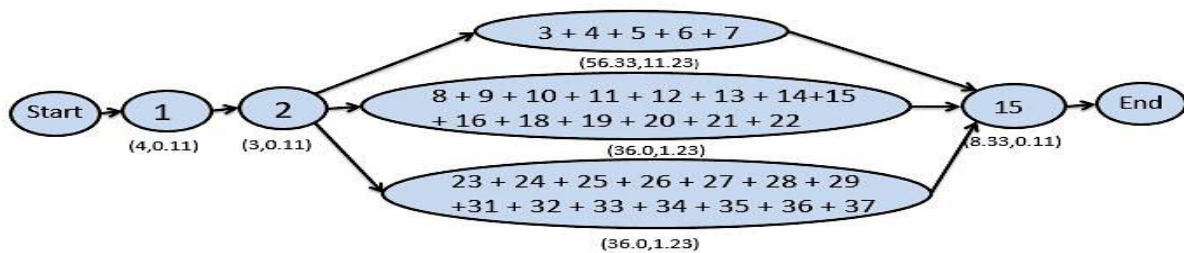

Fig. 12. Step 2, 24 mergers
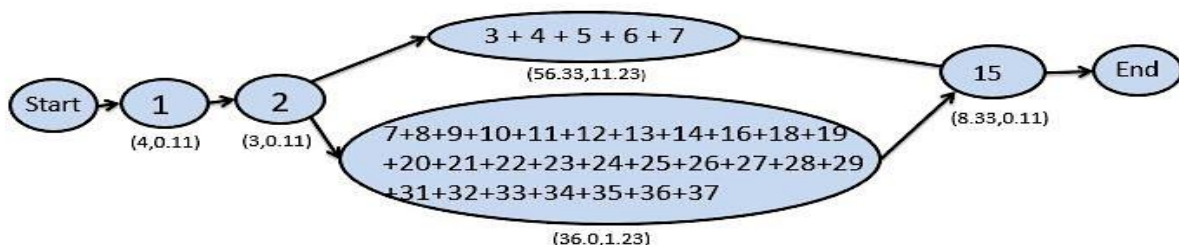

Fig. 13: Step 3, 4 mergers
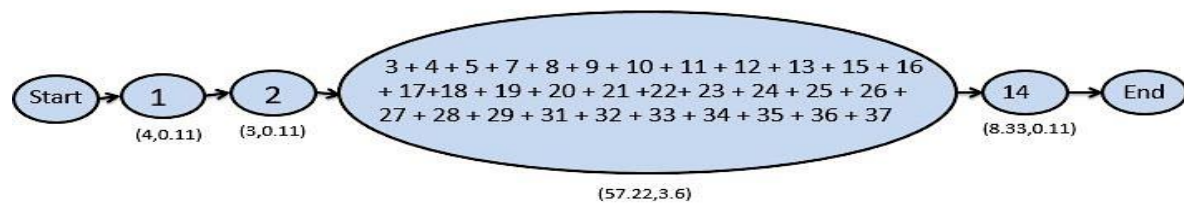

Fig. 14. Step 4, 2 mergers
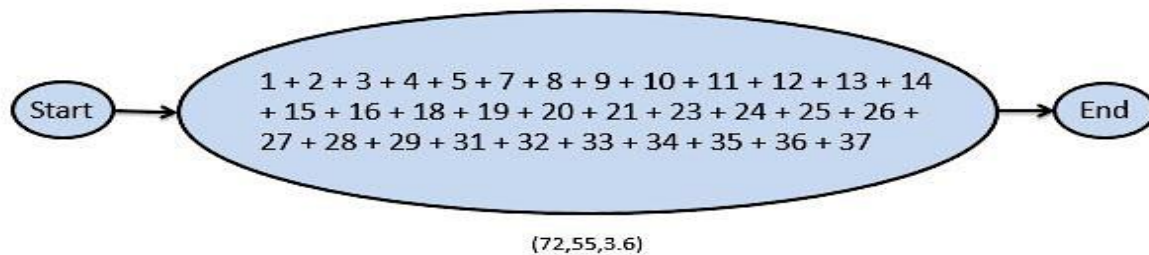
Fig. 15. Step 5, 2 mergers

Fig. 16. Step 6, 2 mergers

5. CONCLUSION

1. Implementation of the M-PERT and LoB scheduling methods on earthwork projects in industrial estates in accordance with Figure 3 concerning the flowchart for applying the M-PERT and LoB methods

2. The factors that influence the implementation of earthwork work are as follows: 1. Selection of savers, 2. Similarities in networks, 3. Combining activities, 4. Understanding PERT activities, 5. Calculations manually, 6. Recalculating PERT, 7. Increasing crash time, 8. Network diagram, 9. Identification of cut and fill, 10. Effect of duration of activity and 11. Continuity of repetitive work.

3. The time of the earthwork project in accordance with the plan is 77 days, after applying the Line of Balance (LoB) method up to 65 days, resulting in a time efficiency of 15.6%

4. Based on the calculation of the time of implementation of earthwork projects using the M-PERT method for 72.55 days, the realization of the implementation was 74 days. Based on these data, then the calculation using the M-PERT method occurs an error of 1.99%

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