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RESEARCH ARTICLE

TIME PERFORMANCE UPGRADE ON TOLL ROAD CONSTRUCTION PROJECT BY M-PERT SCHEDULING IMPLEMENTATION

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ABSTRACT

The annual growth of toll road infrastructure construction in Indonesia is very significant. This infrastructure construction is expected to increase the accessibility and competitiveness of what once were remote areas. Historical data from 1995 to 2001 stated that there were 1722 cases of project duration delay, averaging 11.95% of the initially stated duration. Planning is the most important phase in determining the success of a construction project which will play a major role in the financial revenue of the project. One form of project planning project schedule. This research aims to optimize the baseline project duration that was stated in the initial contract by utilizing the integration of PERT and M-PERT. The scheduling method of M-PERT is the newest development of scheduling systems that was first introduced in 2017 and has the ability to optimizing the project duration up to 8.8%. The statistical analysis done by RII utilization resulted in 10 most influential factors affecting the project duration, which are the ability to combine project activities, manual calculation development, the effect of different activity duration division, duration control, cost control, leadership, good management and supervision, the existing data of road pavement, availability of skilled worker, project management process, and teamwork. The M-PERT implementation optimized the project duration to 24.04 months, clocking 1.96 months or 7.55% upgrade from the initial duration. M-PERT scheduling method has been proven to be feasible and effective in reducing the project duration and delays.

Key words: PERT, M-PERT, Toll Road, Relative Important Index, Optimized the Project Duration.

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INTRODUCTION

The annual growth of toll road infrastructure construction in Indonesia is very significant due to one of the main objective of the current government which is to construct 1000km of new toll roads (Bappenas, 2015). This infrastructure construction is expected to increase the accessibility and competitiveness of what once were remote areas, increasing its market integrity with the domestically and internationally while also increasing the competition and time efficiency (Husin *et al.,* 2015). 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 (Anastasopoulos *et al.,* 2012). Planning is the most important phase in determining the success of a construction project which will play a major role in the financial revenue of the project. One form of project planning is the project schedule, which is an activity that involves setting the duration of the project activities that has to be done from the start to the end of the project. According to Kinkinzaen (2004), a project is a combination of several relevant and relatable activities that must be done in a specific sequence in order to achieve the main goal of the project.

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The project activities are sequenced in a logical sense which means there some activities that could not have been done before finishing the other related activities first.

METHODS

The scope of this research is the toll road construction in Indonesia, focusing only on activities that have the latency average of 11.94% from the initial scheduling. This research aims to optimize the baseline project duration that was stated in the initial contract by utilizing the integration of PERT and M-PERT.

Key Succes Factor (KSF)

The data were gathered from literature studies in order to acquire the most important factors which would then be arranged as the variables in the question items. The questionnaires were spread out to 43 respondents that include project directors, project managers, site managers, and executing consultants. Based on the findings in table 1, it could be observed that the variables are composed of 8 main factor and 48 sub-factor. The result of the questionnaire was analyzed by using the statistical tool of Relative Importance Index (RII) in order to acquire the most important factor in the construction of the toll road

Tabel 1. Key success factor variables

No	Description	Main factors No.	Main factors Name	Kode SF	Sub factors	Index RII	Reference
1	PERT	I	Duration of activity	X1	Distribution of activity duration	0,940	Hajdu, M. (2016)
				X2	The effect of the duration of the division activity is different	0,986	Hajdu, M. (2016)
				X3	Work must start faster	0,949	Hajdu, M. (2016)
				X4	Work must be completed faster	0,902	Hajdu, M. (2016)
				X5	A Possibility of a division of activity duration	0,772	Hajdu, M. (2016)
		II	Scheduling	X6	Network diagrams created at the planning stage	0,907	Lu, M. & AbouRizk, S.M. (2000)
				X7	A final goal of the scheduling phase in the project	0,837	Lu, M. & AbouRizk, S.M. (2000)
				X8	Scheduling in activities can be completed on time	0,888	Lu, M. & AbouRizk, S.M. (2000)
		III	Planning	X9	Break down projects into activities	0,940	Prasetiowati, D.A (2015)
				X10	Determine network time estimates	0,833	Prasetiowati, D.A (2015)
				X11	Describe a diagram in a network	0,777	Prasetiowati, D.A (2015)
2	M-PERT	IV	Activity Analysis	X12	Can combine project activities	0,995	Ballesteros-Peres, P. (2017)
				X13	Calculations can be developed manually	0,991	Ballesteros-Peres, P. (2017)
				X14	A higher similarity in scheduled networks	0,926	Ballesteros-Peres, P. (2017)
				X15	The resulting tool is still accurate but not complicated	0,898	Ballesteros-Peres, P. (2017)
				X16	Apply evenly to the network	0,912	Ballesteros-Peres, P. (2017)
3	ROADWORKS	V	Work Implementation	X17	Time control	0,981	Baccarini (2004)
				X18	Cost control	0,916	Baccarini (2004)
				X19	Quality control	0,893	Baccarini (2004)
				X20	Client satisfaction (service users)	0,828	Baccarini (2004)
				X21	teamwork	0,953	Baccarini (2004)
				X22	Organization goals	0,763	Baccarini (2004)
				X23	Stakeholder satisfaction	0,921	Baccarini (2004)
				X24	Project Management Process	0,958	Baccarini (2004)
				X25	Safety	0,823	Baccarini (2004)
		VI	Supervision	X26	team collaboration culture	0,842	Chen & Chen (2007)
				X27	long-term quality focus	0,767	Chen & Chen (2007)
				X28	consistent goals	0,884	Chen & Chen (2007)
				X29	availability of skilled workers	0,963	Kaotsikouri et al. (2008)
				X30	resource control	0,879	Kaotsikouri et al. (2008)
				X31	Project cost control	0,977	Kaotsikouri et al. (2008)
				X32	Cooperation between team members	0,819	Kaotsikouri et al. (2008)
				X33	In the allotted time	0,795	Kaotsikouri et al. (2008)
				X34	In the budgeted costs	0,791	Kaotsikouri et al. (2008)
		VII	Survey Results	X35	Unrealistic scope, schedule, and budget.	0,874	Christ Hendrickson (2013)
				X36	Planning early and in more aspects.	0,847	Christ Hendrickson (2013)
				X37	Good leadership, management, and supervision.	0,972	Christ Hendrickson (2013)
				X38	Positive client relationships with client involvement.	0,935	Christ Hendrickson (2013)
				X39	A close relationship with the project team.	0,786	Christ Hendrickson (2013)
				X40	Many changes at various stages of progress.	0,870	Christ Hendrickson (2013)
				X41	In the specified performance or specifications	0,781	Christ Hendrickson (2013)
				X42	Accepted service users (client)	0,851	Christ Hendrickson (2013)
		VIII	Data Type Collected	X43	With changes in the minimum scope of work approved	0,930	Santosa (2007)
				X44	Without disrupting the main workflow of the organization	0,814	Santosa (2007)
				X45	Without changing the culture (positive) of the company	0,805	Santosa (2007)
				X46	Road inventory data	0,860	McPherson, K. & Bennett, C.R. (2006)
				X47	Existing pavement layer data	0,967	McPherson, K. & Bennett, C.R. (2006)
				X48	Vehicle traffic data	0,865	McPherson, K. & Bennett, C.R. (2006)

Critical Path Method (CPM)

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. In determining the estimation of the project duration, a critical path that contains a series of activities that has the longest duration and the fastest project completion time (Taha, 2007). It could be concluded that the critical path is a path that went through the critical activities from the start to the end of the project. This path is very influential to the completion time of the project albeit the occurrence of several critical paths in the network of activities. The identification of critical paths has to be done thoroughly by the project manager because in this path lays several crucial activities that could cause major delays on the project.

Program Evaluation and Review Technique (PERT)

PERT is a project management tool that could be utilized in scheduling, managing, and coordinating the work items of a project (setianingrum, 2011). PERT is a system that aims to decrease delays, challenges, and differences between different parts of the project to accelerate the project completion time. This method is not just utilized to determine the most possible project duration but also enables the user to calculate the probability of one or several projects that could be done in the same timeframe.

Manual Program Evaluation and Review Technique (M-PERT)

The scheduling method of M-PERT is the newest development of scheduling systems that was first introduced in 2017 and has the ability to optimizing the project duration up to 8.8% on its trial project of a bridge (Ballesteros-Peres, 2017). The utilization of M-PERT scheduling is the further development of PERT and will be used to optimize the 26 months project duration of the construction of Solo-Kertosono toll road.

RESULTS AND DISCUSSION

Scheduling on road construction

The utilization of PERT and M-PERT integration on the construction of toll road could be observed in figure 1. The preparation work will be the early indication of success while the accelerated duration would be the sustainability of the product of PERT as well as M-PERT.

Table 2. RII generated sub-factor rankings

No.	Main Factor	Kode SF	Sub Factors	Nilai Indek RII (ΣW/ (A*N)
1	IV	X12	Can combine project activities	0,995
2	IV	X13	Calculations can be developed manually	0,991
3	I	X2	The effect of the duration of the division activity is different	0,986
4	V	X17	Time control	0,981
5	VI	X31	Project cost control	0,977
6	VII	X37	Good leadership, management, and supervision.	0,972
7	VIII	X47	Existing pavement layer data	0,967
8	VI	X29	availability of skilled workers	0,963
9	V	X24	Project Management Process	0,958
10	V	X21	teamwork	0,953

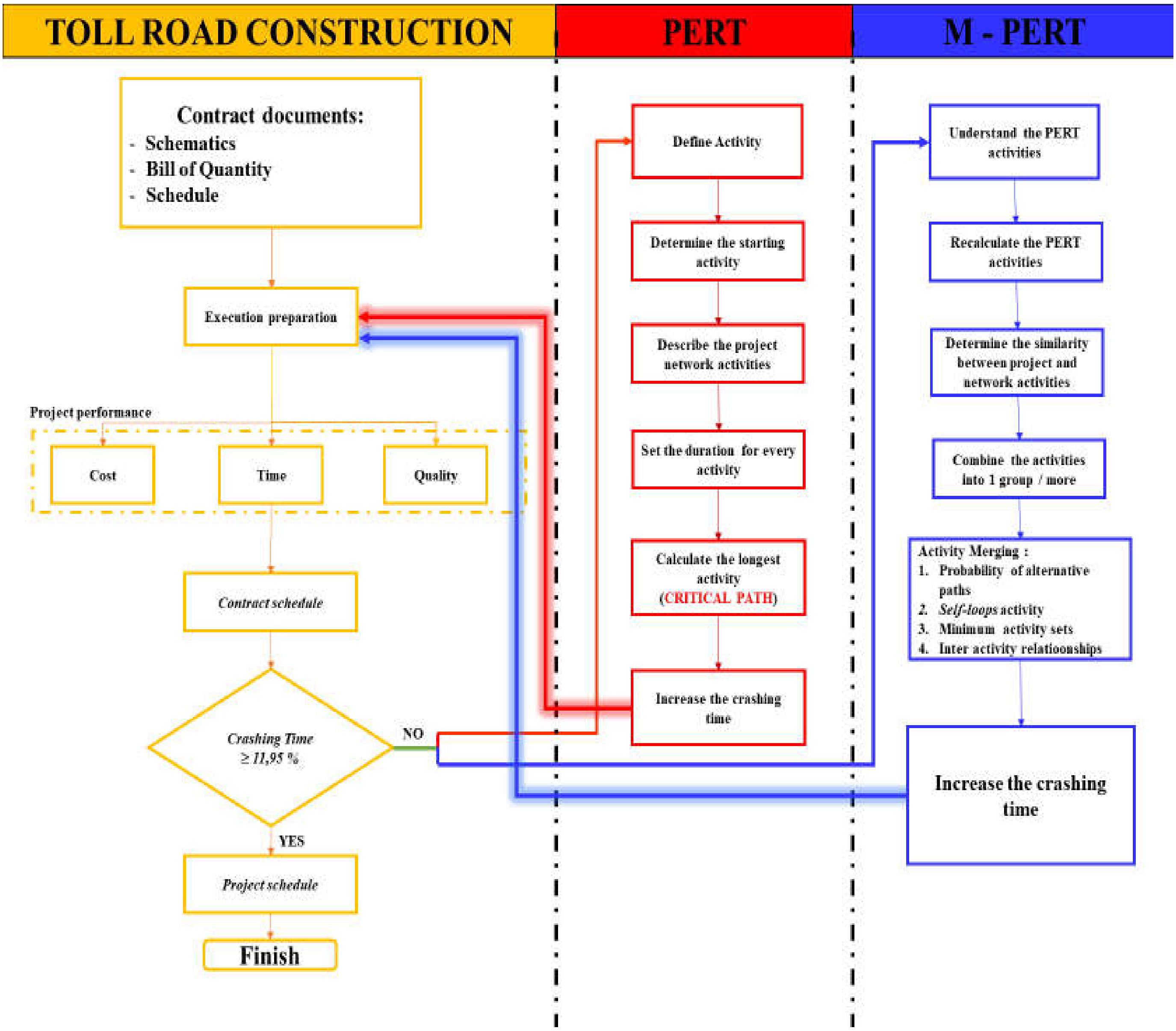

Figure 1. PERT and M-PERT implementation on toll road construction

Relative Importance Indexes

Relative Importance Index (RII) is a method that could be used to analyze the most influential factors regarding the research subject. This method of analysis is done by statistically processing the result of the questionnaires as the input which would be then further processed into the most influential factors. RII would determine the most influential factors in a ranking system based on the value of answers given by the respondents. The reliability concept is how far the result of a research could be trusted. The result of the measurement could be trusted if in more than one implementation it produces a relatively same result (Saifuddin, 2006). The result of the RII measurement from the respondent data could be observed in Table 2. The sorted ranking of the main factors is described in Table 3.

CPM scheduling

The result of CPM method utilization on the toll road construction project could be observed in Figure 2. The CPM of the toll road construction project was generated by recapping all of its critical paths described in Table 4.

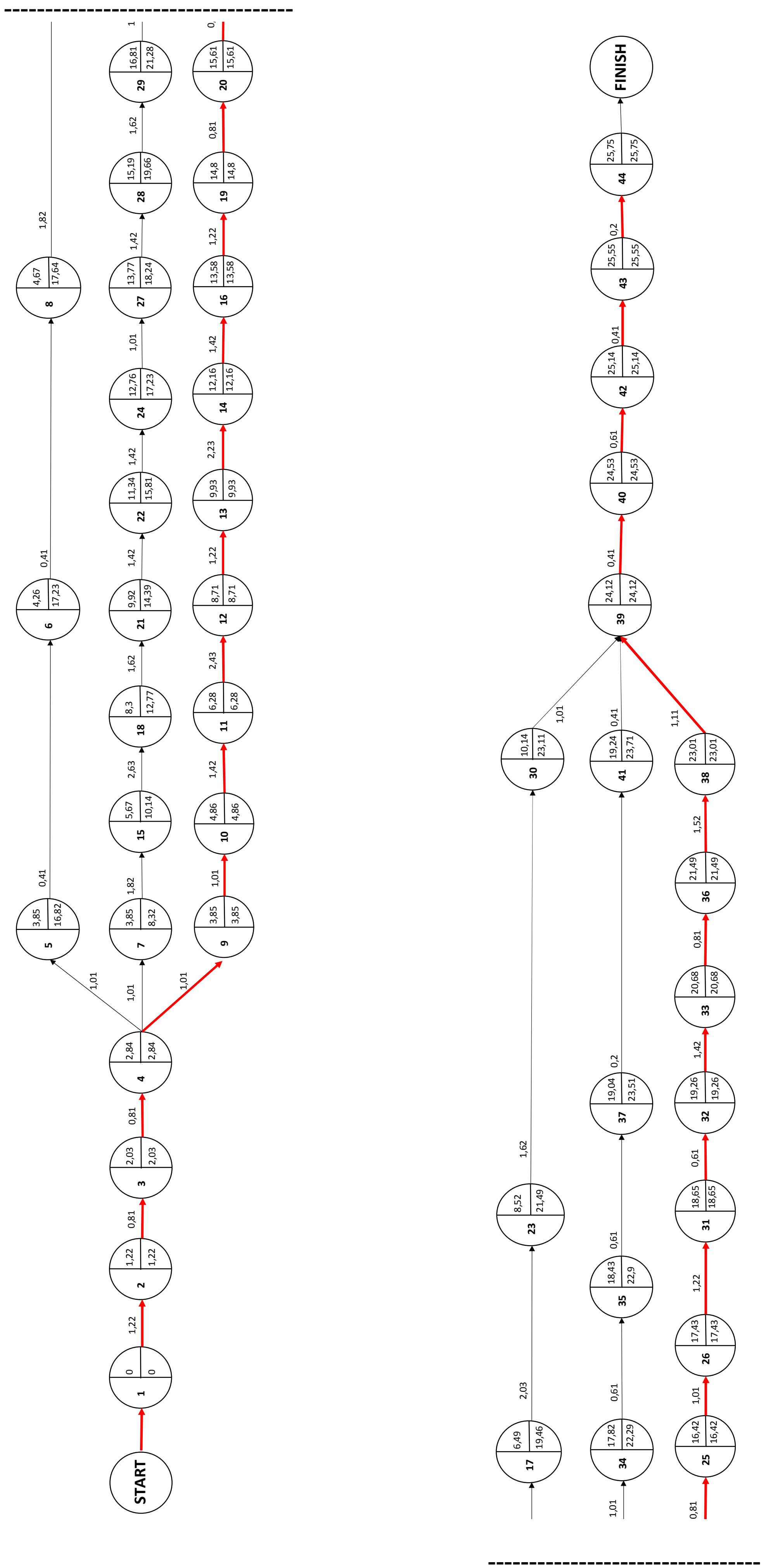

Figure 2. Critical paths on the toll road construction project scheduling

Table 3. Main factor rankings

Existing		Rank	After process	Subfactor	Total	Mean
I	Duration of activity	1	Activity Analysis	5	4,721	0,944
II	Scheduling	2	Duration of activity	5	4,549	0,910
III	Planning	3	Work implementation	9	8,037	0,893
IV	Activity Analysis	4	Scheduling	3	2,633	0,878
V	Work implementation	5	Data type collected	6	5,242	0,874
VI	Supervision	6	Survey results	8	6,916	0,865
VII	Survey results	7	Supervision	9	7,716	0,857
VIII	Data type collected	8	Planning	3	2,549	0,850

Table 4. Critical paths recap

o.	Activity Path	Job Duration	Total Duration	Description
I	1 - 2 - 3 - 4 - 5 - 6 - 8 - 17 - 23 - 30 - 39 - 40 - 42 - 43	1,22-0,81-0,81-1,01-0,41-0,41-1,82-2,03-1,62-1,01-0,41-0,61-0,41-0,20	12,76	
II	1 - 2 - 3 - 4 - 7 - 15 - 18 - 21 - 22 - 24 - 27 - 28 - 29 - 34 - 35 - 37 - 41 - 39 - 40 - 42 - 43	1,22-0,81-0,81-1,01-1,82-2,63-1,62-1,42-1,42-1,01-1,42-1,62-1,01-0,61-0,61-0,20-0,41-0,41-0,61-0,41-0,20	21,27	
III	1 - 2 - 3 - 4 - 9 - 10 - 11 - 12 - 13 - 14 - 16 - 19 - 20 - 25 - 26 - 31 - 32 - 33 - 36 - 38 - 39 - 40 - 42 - 43	1,22-0,81-0,81-1,01-1,01-1,42-2,43-1,22-2,23-1,42-1,22-0,81-0,81-1,01-1,22-0,61-1,42-0,81-1,52-1,11-0,41-0,61-0,41-0,20	25,75	Critical Path

Table 5. PERT calculation results

Activity	Description	Unit	Pessimistic	Optimistic	Time	Expected Time (Month)	Variance	Variance Critical Path
1	Mobilization	Ls	1,94	0,61	1,22	1,24	0,05	0,05
2	Removal of Existing Tree	Each	1,30	0,41	0,81	0,82	0,0221	0,0221
3	Site Clearing	M2	1,30	0,41	0,81	0,82	0,0221	0,0221
4	Working In and Dealing	Ls	1,62	0,51	1,01	1,03	0,0345	0,0345
5	Deck Drain Type 1 with Accessories	Each	0,65	0,20	0,41	0,41	0,0055	
6	Drain Pipe D=20cm with Fitting and Supports	M1	0,65	0,20	0,41	0,41	0,0055	
7	Geotextile for Subsurface Drainage	M2	2,92	0,91	1,82	1,85	0,1117	
8	RC Spun Pipe	M1	2,92	0,91	1,82	1,85	0,1117	
9	Static Loading Test for Pretensioned Spun Concrete Pile	Each	1,62	0,51	1,01	1,03	0,0345	0,0345
10	Blinding Stone	M3	2,27	0,71	1,42	1,44	0,0676	0,0676
11	Reinforcing Steel Plain Bars BJTP-24	Kg	3,89	1,22	2,43	2,47	0,1985	0,1985
12	Solid Sodding	M2	1,94	0,61	1,22	1,24	0,0496	0,0496
13	Structural Concrete Class C-1 (Abutments, Pier Footings)	M3	3,56	1,11	2,23	2,26	0,1668	0,1668
14	Vehicle Guardrail Type A	M1	2,27	0,71	1,42	1,44	0,0676	0,0676
15	Granular Backfill	M3	4,21	1,32	2,63	2,68	0,2330	
16	PC-I Girder Nominal Span	Each	1,94	0,61	1,22	1,24	0,0496	0,0496
17	U-Ditch	M1	3,24	1,01	2,03	2,06	0,1379	
18	Aggregate Base Class A	M3	2,59	0,81	1,62	1,65	0,0882	
19	Anchor Bar & Accessories	Kg	1,30	0,41	0,81	0,82	0,0221	0,0221
20	Elastomeric Bearing Pad 300 x 350 x 36 (Mov.)	Each	1,30	0,41	0,81	0,82	0,0221	0,0221
21	Asphalt Concrete - Base	Ton	2,27	0,71	1,42	1,44	0,0676	
22	Bituminous Prime Coat	Kg	2,27	0,71	1,42	1,44	0,0676	
23	DS-4 (Mortared Rubble)	M	2,59	0,81	1,62	1,65	0,0882	
24	Sub-grade Preparation	M2	1,62	0,51	1,01	1,03	0,0345	
25	Pretensioned Spun Concrete Pile	M1	1,62	0,51	1,01	1,03	0,0345	0,0345
26	Structural Concrete Class B-1-2 (Diaphragms of PCU/PCIGirders)	M3	1,94	0,61	1,22	1,24	0,0496	0,0496
27	Bituminous Tack Coat	Kg	2,27	0,71	1,42	1,44	0,0676	
28	Concrete Pavement	M3	2,59	0,81	1,62	1,65	0,0882	
29	Wet Lean Concrete (t = 10 cm)	M3	1,62	0,51	1,01	1,03	0,0345	
30	Catchbasin, DC-1	Each	1,62	0,51	1,01	1,03	0,0345	
31	Chainlink Fence	M1	0,97	0,30	0,61	0,62	0,0124	0,0124
32	ROW fence, Tiype 1 (Concrete Panel)	M1	2,27	0,71	1,42	1,44	0,0676	0,0676
33	Expansion Joint Type C-1 (20mm)	M1	1,30	0,41	0,81	0,82	0,0221	0,0221
34	Anti Stripping Agent	Kg	0,97	0,30	0,61	0,62	0,0124	
35	Asphalt Concrete - Binder Course	Ton	0,97	0,30	0,61	0,62	0,0124	
36	Structural Concrete	M3	1,94	0,61	1,22	1,24	0,0496	0,0496
37	Asphalt Concrete - Wearing Course	Ton	0,32	0,10	0,20	0,21	0,0014	
38	Guide Sign Type C-1	Each	0,97	0,30	0,61	0,62	0,0124	0,0124
39	Kilometer Post	Each	0,65	0,20	0,41	0,41	0,0055	0,0055
40	Regulatory and warning signs type A-1	Each	0,97	0,30	0,61	0,62	0,0124	0,0124
41	Road Marking Type A (General Application)	M2	0,65	0,20	0,41	0,41	0,0055	
42	Guard Rail End Section	Each	0,65	0,20	0,41	0,41	0,0055	0,0055
43	Demobilisasi	Ls	0,32	0,10	0,20	0,21	0,0014	0,0014

PERT Scheduling result

Step1.

PERT balances the 3 activity duration estimations in order to acquire the expected time with formula 1:

$$\frac{\text{(Optimistic duration + (4 x The most possible duration) + Pessimistic duration)}}{6}$$

$$t_e = \frac{t_o + (4.t_m) + t_p}{6} \quad (1)$$

Whereas :

te = expected duration;
to = optimistic duration;
tm = moderate duration;
tp = pessimistic duration

Step 2.

Variance calculation of every activity with formula 2:

$$V = \left(\frac{T_p - to}{6}\right)^2 \quad (2)$$

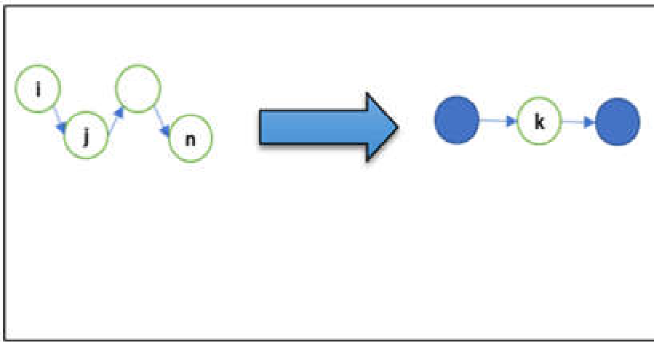

Figure 3. Series combination on M-PERT

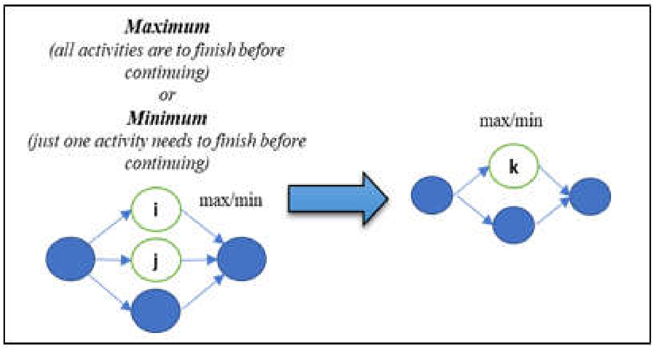

Figure 4. Parallel combination on M-PERT

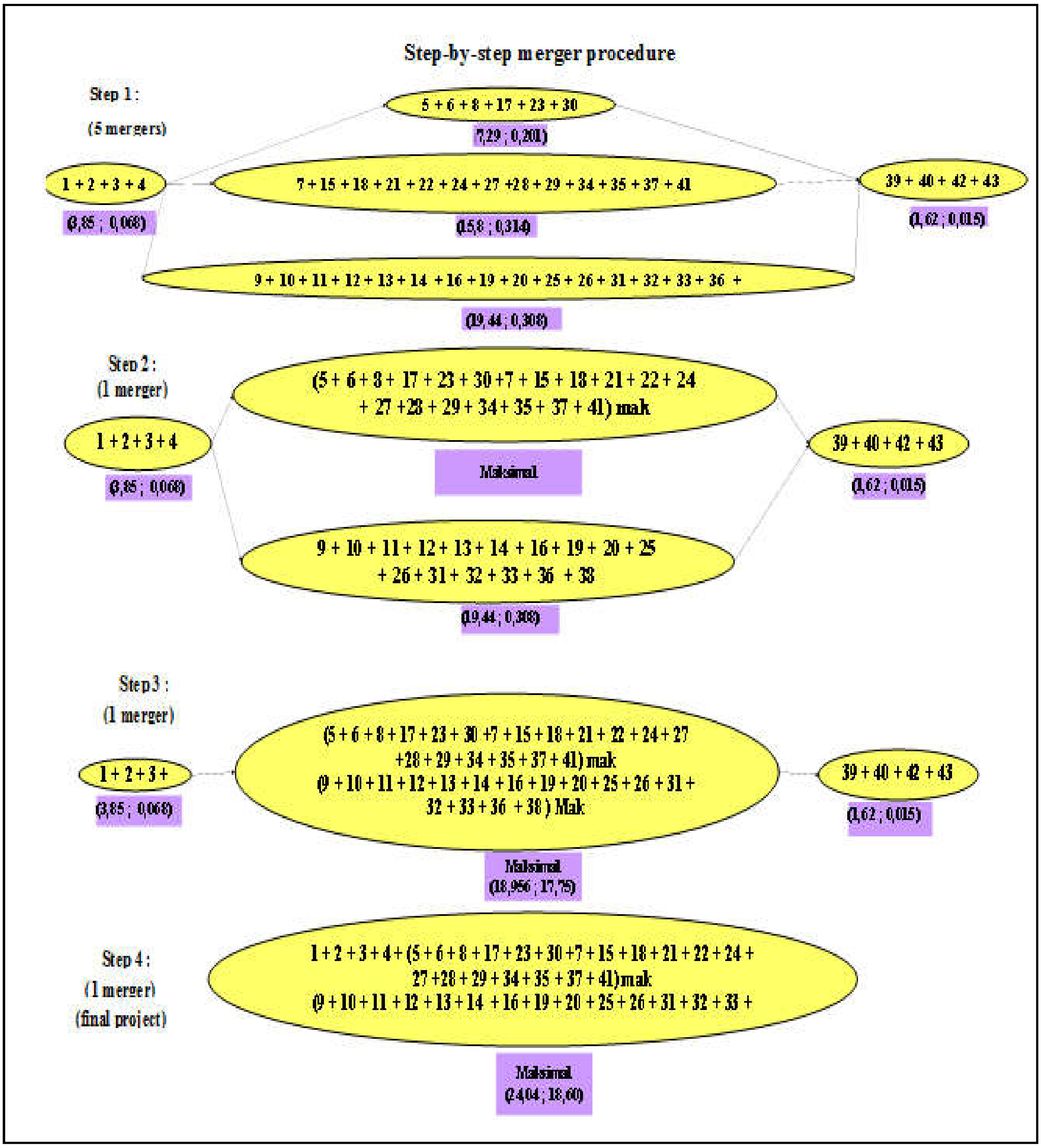

Figure 5. The final combination of all activities on M-PERT

Whereas :

V = variance;
tp = pessimistic duration;
to = optimistic duration

Step 3.

Project variance calculation by adding up all of the variances in the critical path with formula 3:

$$\sigma_p = \sqrt{\Sigma v} \quad (3)$$

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

The conclusion of PERT measurement in table 5 resulted in the following project standard deviation:

Σvp = 1, 08
σp = √1,08
= 1,04 month

The pert utilization was concluded to be able to optimize the duration of 1.04 months or 4% of the initial duration of 26 months.

M-PERT scheduling result

The calculation done in M-PERT utilization was the same with PERT, with the results shown in Table 5 describing the acquired parameters from the M-PERT utilization and its average duration and standard deviation sequence shown in figure 3.

The first stage of M-PERT method consisted of 5 series of combinations which is:

1. Initial activities, with the duration of : 3,85 months
2. Initial activities standard deviation: 0,068
3. Drainage, with the duration: 7,29 months
4. Drainage standard deviation : 0,201
5. Road, with the duration : 15,80 months
6. Road standard deviation : 0,314
7. Bridge, with the duration : 19,44 months
8. Bridge standard deviation: 0,068
9. Final activities, with the duration: 1,62 months
10. Final activities standard deviation: 0,015

The result and schematics of the combination of the series could be observed in figure 5, which could also be interpreted as the 1st step. After the first step, the 2nd step consisted of combining the parallel activities could be observed in Figure 4. The maximum parallel combination was chosen because every activity must be done before another cycle could be started utilizing the Pablo Ballesteros-Perez equation that could be observed in Figure 4.

The equations that were used for the parallel combination shown in figure 4 were the equation 4 and 5:

$$\mu k= \mu i\phi(\delta)+ \mu j(1-\phi(\delta))+ \theta\phi(\delta) \quad (4)$$

$$\sigma k2=(\sigma i2+\mu i2)\phi(\delta)+(\sigma j2+\mu j2)(1-\phi(\delta))+(\mu i+\mu j)\theta\phi(\delta)- \mu k2 \quad (5)$$

a. The first parallel combination was done on the drainage activity which resulted in:

- The combination of drainage and road duration: 18.96 months
- A Standard deviation of the combination: 17.75
- The second parallel combination was done by combining the drainage with the road and bridge activity which resulted :
- The combination of drainage, road, and bridge duration: 18.57 months
- A Standard deviation of the combination: 18.51
- The 2nd and 3rd step of the combination could be observed in figure 5.

The outcome of the 4th step of the series-parallel combination between each of the initial activities are:

- The final combination duration: 24.04 months
- Final combination standard deviation: 18.6

The results and schematic of the 4th step could be observed in Figure 5, the result which also combines all of the activities into 1 big activity of the whole project. M-PERT implementation has resulted in the project duration of 24 months, optimizing it for 7.55%.

Conclusion

1. The RII statistical analysis resulted in 10 sub-factors that have the most influence on the M-PERT scheduling of a toll road project which are the combination of project activities, the start of manual calculations, the effect of different activity durations, duration control, project cost control, leadership, adequate management and supervision, the data of the existing road pavement, the availability of skilled workers, project management process, and teamwork.
2. The PERT implementation resulted in the optimized duration of 24.95 months, which decreased 1.04 months or 4% of the initial project duration of 26 months.
3. The M-PERT implementation optimized the project duration to 24.04 months, clocking 1.96 months or 7.55% upgrade from the initial duration.
4. M-PERT scheduling method has been proven to be feasible and effective in reducing the project duration and delays. A main conclusion of the study may be presented in a short Conclusions section, which may stand-alone. It should not repeat the Results, instead provide significant findings and contribution to the study.

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