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MULTI-SPAN BRIDGE WORK BASED ON LINE OF BALANCE AND CRITICAL PATH METHODS INTEGRATION IN LIGHT RAPID TRAIN

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ABSTRACT

The growth rate of vehicles in Indonesia today, especially in Jakarta, is very high, this can be seen from the high value of The Congestion Level in Jakarta recorded in the figure of 58% coupled with the poor mode of public transportation to solve transportation problems by building Light Rapid Train whit system Multi-Span Bridge, the development of this project turned out to have other problems, this was due to the narrow extent of the land owned by the government in Jakarta, which necessitated the construction of this light rail line adjacent to the arterial and toll road lines in the city. The author used the Line of Balance integration method with Critical Path, and the author used SPSS edition 25 to analyze the key success factor to the optimization of time performance then validate with the LOB Method for the liner scheduling process to obtain optimum results from the work duration and summarize the Buffer time while CPM is to get a critical trajectory, The results of this study obtained the most success factors and obtained the optimization of the duration of the project faster by 16.77 % of the initial schedule.

Keywords: line of balance, critical path method, time optimization, light rail transit.

INTRODUCTION

Construction of the Light Rapid Transit (LRT) project as an alternative transportation in Jakarta, on the basis of this, the government passed the Ministry of Public Works and the Transportation Agency to innovate in solving transportation problems by building light railroad overpasses with the Multi-Span Bridge system, construction of this project turned out to have other problems This is due to the limited land owned by the government in Jakarta, which requires that the construction of this light rail line be directly adjacent to arterial lines and inner-city toll roads, this results in narrowing of roads on these lines so that the construction of light rail lines has a time limit in construction work, where the limitation of time is from 22:00 to 04:00 with a limited time and the narrowness of this work area has an impact on the delay in completion of this light railroad construction project. With a better planning process, it can be obtained that the optimization of project completion is

THEORY

Project planning

Project planning is a process of making systematic efforts to achieve goals and objectives in completing projects including preparing all the resources needed to obtain results and functions such as those set at the beginning. Scheduling is defined as the process of managing time from an operating activity [1], successful scheduling should include the proper sequence of activities [2], in general scheduling aims to minimize processing time, subscription waiting time, and inventory levels, as well as efficient use of facilities, labor, and equipment. Scheduling is arranged in consideration of the various limitations that exist in scheduling construction projects and efficient cost [23], during the planning stage, the schedule [18] tools used should provide answers to specific question regarding activities and processes of a project [8] that have many methods starting from Bar Chart, S Curve, Critical Path Method, Line of Balanceext.

Line of balance

The LoB technique is very suitable for repetitive [4] projects, however, it may be adapted for non-repetitive projects as well [3] repetitive project can be classified into two broad categories such a liner and non-linear [13]. Infrastructure work has a very dynamic complexity and scheduling methods Line of Balance or linear lines [10] are usually very effective for projects with relatively few activities and are widely used for scheduling repeated activities for infrastructure projects such as highway construction projects, airport runways, tunnels or tunnels or manufacturing industry projects Line of Balance is a diagram that can show when and where additional workforce or tools are needed in the work unit [4] can also inform at a glance what is wrong in the progress of the activity and can detect potential future disturbances. The benefit of lean construction method has been shown with the increasing achievement of many construction projects from its every activity steps [6].

Thus LoB has a better understanding of projects that have repetitive activities compared to other methods, the application of the Line of Balance method can streamline time performance up to 20% [5] the use of the Line of Balance method can provide information if there are jobs that intersection is shown in Figure-1[8].

VOL. 14, NO. 17, SEPTEMBER 2019 ISSN 1819-6608
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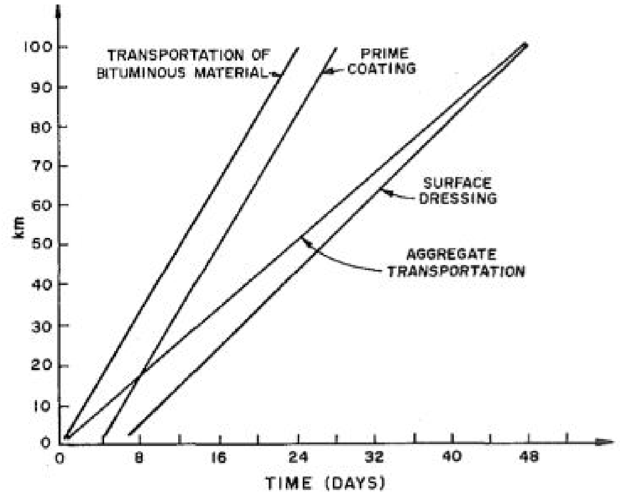

Figure-1. Line of Balance intersection [6].

In Figure-1, it can be seen that the prime coating work intersects with the aggregate transport work, if each of the jobs has the same crew [9], the work must be analyzed so that the work does not intersect between each activity 2 [6] The duration of an activity i (d_i) taken by a single crew in one unit can be calculated based on the work quantity and out put rate of the crew employed, using any formula similar to that of Eq. (1) [7]

$$d_i = \frac{work\ hours\ of\ activity\ i\ in\ one\ unit}{work\ hours/day} \quad \ldots\ldots\ldots\ldots\ (1)$$

$$D_i = d_i + ST_{in} - ST_{il} = d_i + (N-1)/R_{ai} \quad \ldots\ldots\ (2)$$

In which ST_{iN} =start time of the last unit; ST_{i1}=start time of the first unit, and Di = duration along all units of activity i. overlapping activities are generalized to represent repetitive activities. For this generalized to be possible, the duration has the basic LoB calculations performed, the duration of an activity i overall units (D_i) can be calculated is assumed constant in all units of repetitive activity. As seen in eq. (2) [8].

Critical path method

The CPM [20] is used to represent, via nodes and arrows in a network diagram [21], the logical sequence and interrelation fall activities of a project [16], The Critical Path Method (CPM) is a very efficient scheduling procedure for larger projects [14], in a project, the Critical Path Method (CPM) determines the project completion time and the activities on the critical path One of the main reasons was Critical Path Method vulnerability to sequence changes of work between the repetitive typical units, which is, on repetitive projects, a matter of choice and strategy and frequently depends on unforeseen circumstances [4] Critical Path Method is quite the opposite, it is in effective and cumbersome for scheduling liner continuous projects but extremely effective for more complex and discrete type project [15]

Line of balance and critical path method integration

Project work that has a recurring nature of its activities requires scheduling that ensures the use of activities of an activity does not interfere with other activities both in terms of resources and others and still maintains the limits of resource dependence. The CPM (Critical Path Method) method that is often used for scheduling planning on projects has disadvantages to repetitive project scheduling [8] while LOB methods are designed for repetitive jobs that have a relatively small complexity level [9] for the Line of method Balance is applied at the beginning to analyze activities that have the potential to overlap and determine Buffer time so that there are no resources waiting for work for other jobs then apply the CPM (Critical Path Method) method to determine the amount of duration of work and determination of Floats time and project resources from each activity. So that it is expected that the integration of these two methods can provide a more optimal scheduling plan, Scheduling of repetitive projects represents a challenge for construction planners and managers. Classical CPM analysis does not suit characteristics of repetitive projects, whereas LoB lacks the analytical qualities of CPM scheduling [10]

Infrastructure and light rail transit

Infrastructure is a basic requirement in the organization of the structural system for economic security both by the private sector and the public sector, infrastructure can facilitate economic movement from one region to another, infrastructure is a physical system that provides transportation, irrigation, drainage, building buildings, and other public facilities, which is needed to fulfil basic human needs both social needs and economic needs. In this case, things related to infrastructure cannot be separated from each other. Environmental systems can be connected because of the infrastructure that supports social systems and economic systems. The availability of infrastructure has an impact on the social system and economic system that exists in the community. So infrastructure needs to be understood as the basics in taking policy, [11] Infrastructure [19] management systems are concerned to mainly whit life cycle analysis and continuous assessment of network performance [12] LRT is designed to accommodate a variety of environments, including roads, highways, railways and pedestrians, these characteristics are the differentiators of other rail models, because of the flexibility of this design.

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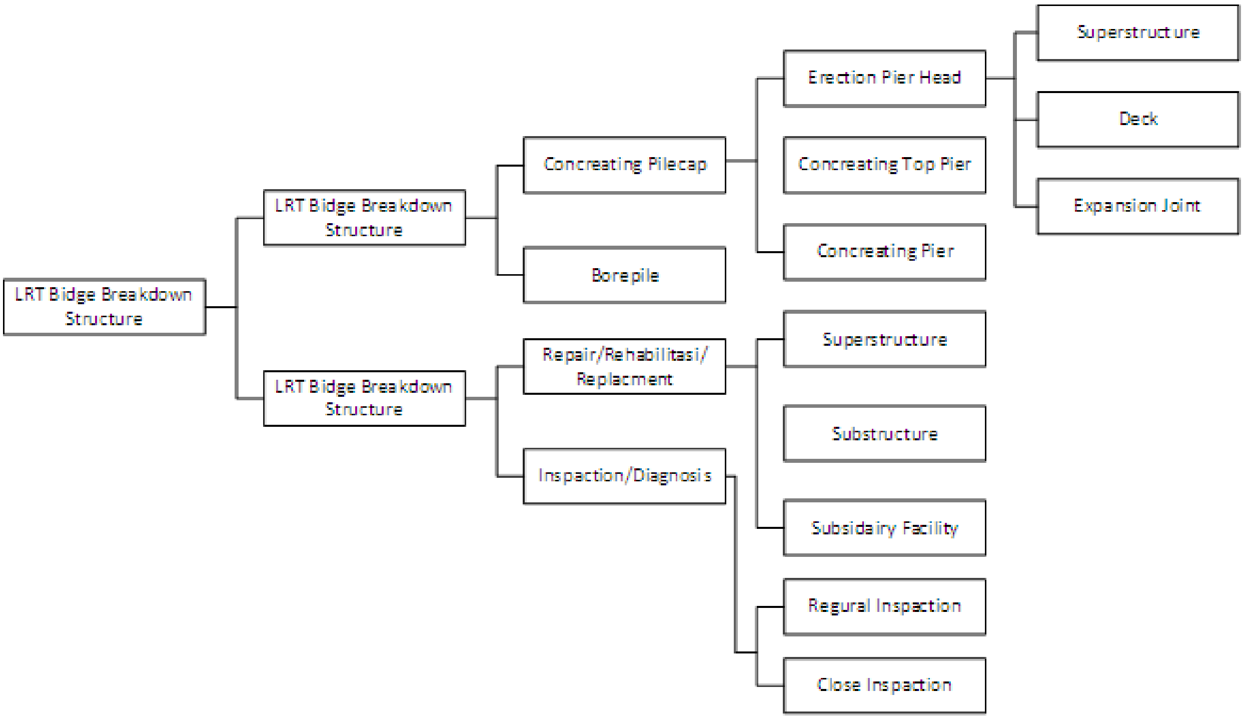

Figure-2. LRT infrastructure breakdown.

LRT is generally cheaper to build and operate than the model other works. The construction of LRT starts from Borepile work then pile cap work and pier work where pier works are divided into several segments depending on Pier height followed by pier head erection then the u-shape erection the Breakdown cost in the construction LRT as seen in Figure-2 above.

RESEARCH METHOD

In this research, the author divides into two data, namely primary data obtained from interviews with 38 correspondents to obtain data on the most influential factors where the dependent variable (Y) is time performance and independent variable (X) are scheduling, productivity and design, resource and external management, then secondary data in the form of data such as master schedule data, cost budget design, and bill of quantity to be used in case studies. From the 40 questionnaires sent there were 5 questionnaires that did not return, so the percentage of the questionnaire was 88.88%.

Data processing

In this research, there are top 12 sub-factors that influence the integration of the Line of Balance method and the Critical Path Method on the Multi-Span Bridge on the light railroad construction project shown in Table-1 Data obtained from questionnaire on 35 respondents selected and before being asked first to experts to simplify the process in providing answers to the questions given, there are 38 questions that will be carried out statistical analysis using Tools SPSS 25 from the results of the SPSS analysis will be obtained whether these variables pass the reliability and validity tests as in the flowchart see in Figure-3 so that the results of these variables can be declared valid and have a significant effect on project time performance.

VOL. 14, NO. 17, SEPTEMBER 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-1. Main factor and Sub Factor.

KODE SF	Var	Main Faktor	Sub Faktor
X1-1	X1	*LoB & CPM*	Analyze work unit schedules
X1-2			Labor analysis
X1-3			Optimization of project time duration
X1-4			Create project activity diagrams
X1-5			Buffer Time Analysis
X1-6			Repeated job analysis
X1-7			Resource analysis
X1-8			Determine work time
X1-9			Determination of duration of work
X1-10			Job sequence analysis
X1-11			Determination of critical paths
X1-12			Relations between activities

As could be seen in Table-1 that there is 12 sub-factors in the main factor of Line of Balance and Critical Path Method that will be analyzed a dominant factor in Line of Balance and Critical Path Method integration.

As could be observed in Figure-3 below that there are two processing namely validity and reliability test, the paper will make Optimization of time as the research subject. It is hypothesized that time schedule of railway Y will be impacted by 3 independent variables:

- X1(Scheduling LoB & CPM),、
- X2(Multi-Span Bridge), and、
- X3(Resource management & external factors Light Rapid Transit)

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \quad \text{.........} (4)$$

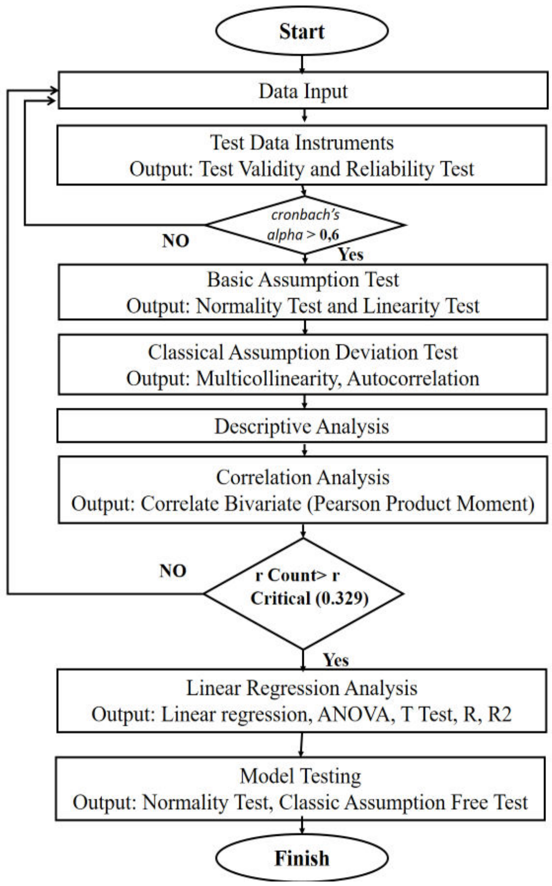

Figure-3. Data processing flowchart.

Among them $\beta_0, \beta_1, \beta_2, \beta_3$ will be served as parameters to be determined, ε will be used as random error, moreover, it requires Eε=0 [17] to run this analysis we need correspondents the following was the position of the respondents seen in Figure-4.

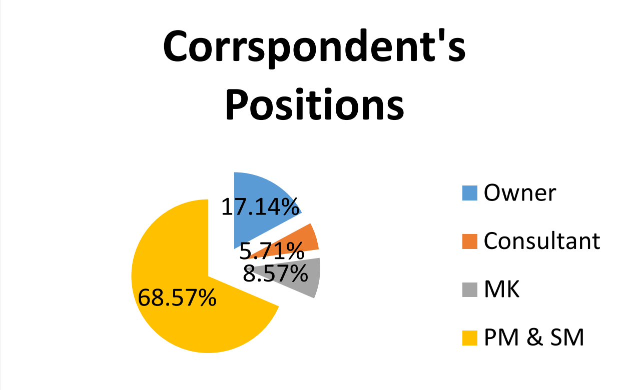

Figure-4. Correspondent's positions.

From Figure-4 it can be seen that the majority of the correspondent's positions are at the Project manager level and this site manager can provide an accurate assessment of the questions given. The percentage of respondents' work experience is shown in Figure-5.

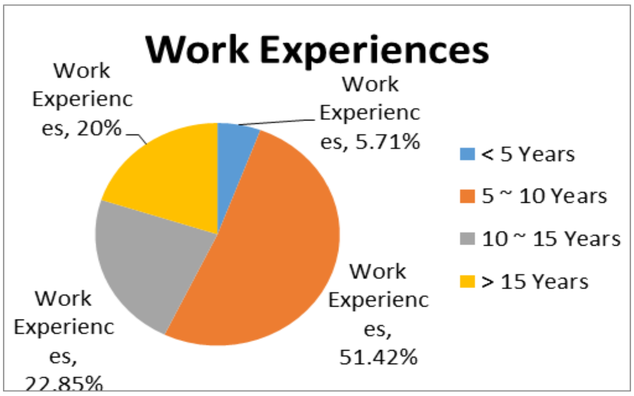

Figure-5. Work experience.

From Figure-5 the work experience of each respondent, there were more respondents who had long work experience; this could be represented on the project under study, as for the percentage of the type of project seen in Figure-6.

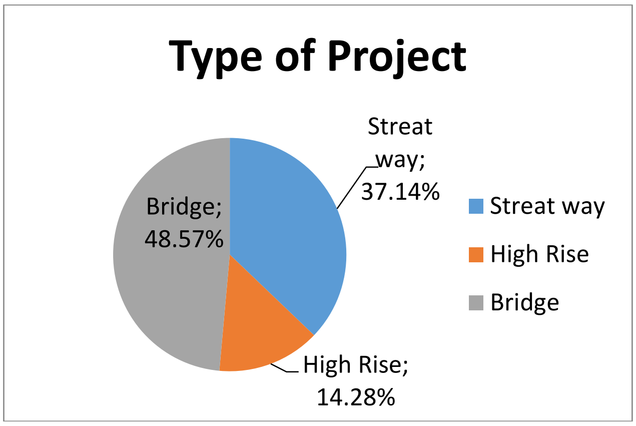

Figure-6. Type of project.

Reliability test

From the results of statistical analysis using SPSS 25, an analysis will be obtained whether these variables pass the reliability and validity tests as in the flowchart see in Figure-3 so that the results of these variables can be declared valid and have a significant effect on project time performance. The value of Cronbach Alpha is obtained as shown in Table-2 through Table-4.

Table-2. X1 Reliability.

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.782	.975	13

From Table-2 the value of Cronbach Alpha, variable X1 can be seen that the Cronbach alpha value is 0.782 > 0.600 [14] that means all questions in the variable are declared consistent.

Table-3. X2 Reliability.

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.790	.975	11

From Table-3 the value of Cronbach Alpha, variable X2 can be seen that the Cronbach alpha value is> 0.600 so that all questions in the variable are declared consistent.

Table-4. X3 Reliability.

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.783	.977	13

VOL. 14, NO. 17, SEPTEMBER 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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From Table the value of Cronbach Alpha, variable X3 can be seen that the Cronbach alpha value is> 0.600 so that all questions in the variable are declared consistent.

Validity test

From the results of statistical analysis using SPSS 25 obtained the Pearson correlation value as shown in Table-5 through Table-7.

Table-5. X1 and Y correlation.

Correlations			
		X1	Y1
X1	Pearson Correlation	1	.904**
	Sig. (2-tailed)		.000
	N	35	35
Y1	Pearson Correlation	.904**	1
	Sig. (2-tailed)	.000	
	N	35	35
**. Correlation is significant at the 0.01 level (2-tailed).			

From Table-5 it can be seen that the value of the Pearson correlation from X1 to Y, [13] has the value r> from r table so that all questions in each variable are declared valid and have a significant relationship to time performance.

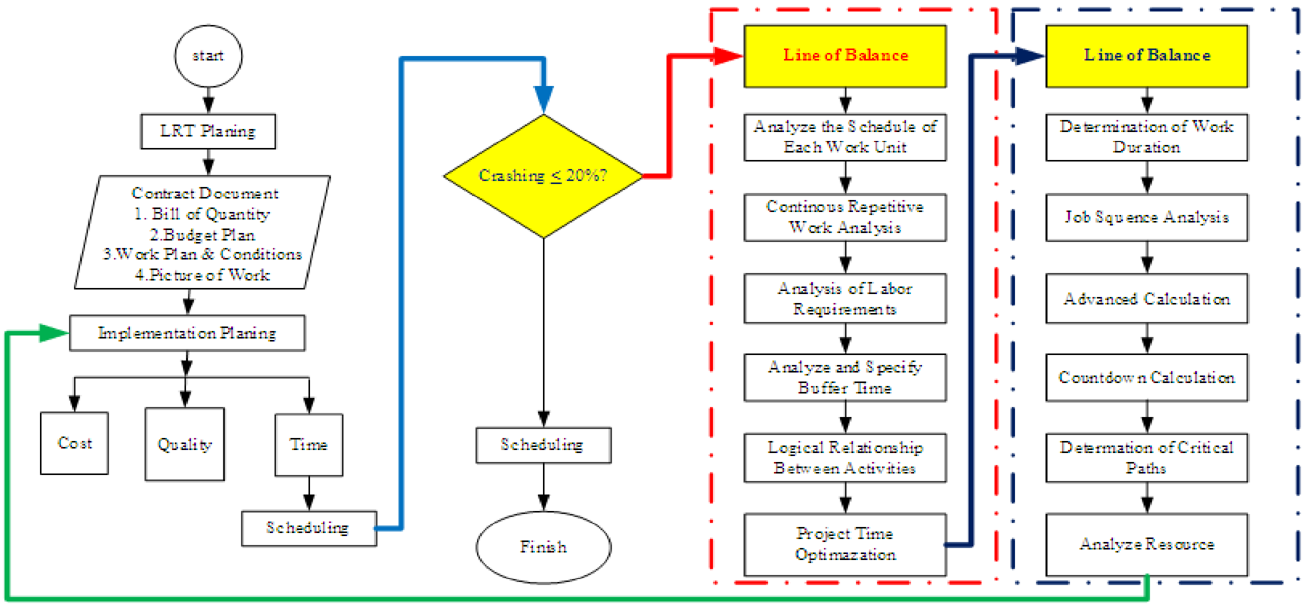

Figure-7. Research staging.

Table-6. X2 and Y correlation.

Correlations			
		X2	Y1
X2	Pearson Correlation	1	.947**
	Sig. (2-tailed)		.000
	N	35	35
Y1	Pearson Correlation	.947**	1
	Sig. (2-tailed)	.000	
	N	35	35
**. Correlation is significant at the 0.01 level (2-tailed).			

From Table-6 it can be seen that the value of the Pearson correlation from X1 to Y, [13] has the r value> from r_{table} so that all questions in each variable are declared valid and have a significant relationship to time performance

Table-7. X3 and Y correlation.

Correlations			
		X3	Y1
X3	Pearson Correlation	1	.943**
	Sig. (2-tailed)		.000
	N	35	35
Y1	Pearson Correlation	.943**	1
	Sig. (2-tailed)	.000	
	N	35	35
**. Correlation is significant at the 0.01 level (2-tailed)			

From Tables 5 to 7 it can be seen that the value of the Pearson correlation from X1 to Y, X2 to Y, X3 to Y [15] has the r value> from r_{table} so that all questions in each variable are declared valid and have a significant relationship to time performance, so obtained coefficient of linear regression multiple equations are as follows:

$$Y = 0.289 - 0.31.X1 + 0.258.X2 + 0.13.X3 \qquad \ldots\ldots (5)$$

Where:
Y = Time Performance
X1 = Scheduling
X2 = Productivity and Design
X3 = Resource and external management

From equation number 5the results of statistical above analysis and processing of questionnaire data, the influential factors that will be used as staging in this research are shown in Figure-7.

Validation and case studies

The data taken in the validation of this case study is on the construction of the JABODEBEK lightweight railway line specifically at the Kuningan - Dukuh Atas Jakarta section which consists of 3 stations and 120 Pier where the distance from the pier to pier is 30 meters.

Line of balance

In this study, we will implement the Line of Balance scheduling method, where the data used is obtained directly from the rapid train Light construction project. where this research is limited only to the Kuningan to Dukuh Atas segments, starting from Pier no 210 ~ Pier no. 230 where there are 20 Pier distances - each Pier is 30 meters, the first step in the Line of Balance method is to analyze each activity and then analyze the repetitive activities followed by analyzing resources and determining buffer times and the logical relationship between repetitive activities on railroad construction projects:

a) Excavation Pile Cap

b) Pouring Concrete Pile Cap

c) Pouring Concrete Pier (Phase 1)

d) Pouring Concrete Pier (Phase 2)

e) Pouring Concrete Pier (Phase 3)

From logic work relationship, we start to analyze the schedule After the Start and Finish time of the overall 20 Pier work package for the LRT project is calculated, for example in the pile cap excavation work the total duration in the Pile cap excavation package is 7 days/pier x 20 Pier (Total Pier) = 140 days, of the total duration the work shows in Table-8.

VOL. 14, NO. 17, SEPTEMBER 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-8. Schedule of LoBs on LRT projects.

No	Activity	Duration of Perception (Day)	Total 20 Pier Duration (Day)	Start Package	Finish Package
1	Excavation Pile cap	7	140	0	140
2	Concreting pile cap	6	120	9	129
3	Concreting Pier phase 1	7	140	16	156
4	Concreting Pier phase 2	11	220	28	248
5	Concreting Pier phase 3	15	300	34	334

In the calculation of Table-8 above, it is estimated that the completion time for one pier is 65 days which is in pier phase 3 (34 + 15) casting which is on day 49. The delivery rate for each subsequent pier is every 15 days thereafter. So the total duration of completion of 20 piers is 334 days. As for diagram Line of Balance on the Light Rapid Train development project shown in Figure-9

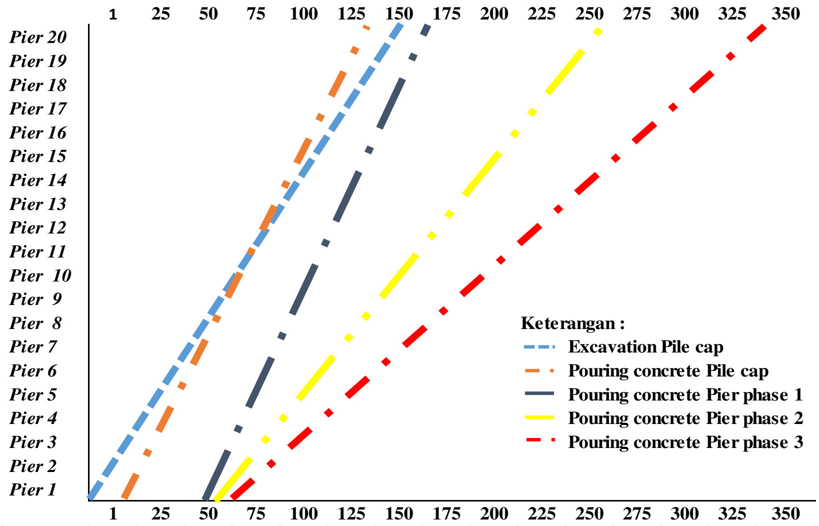

Figure-8. LoB diagram on the LRT project.

As seen in Figure-9 that excavation work have intersects whit pouring concrete that mean the project have a conflict in resource so start to analyze the schedule, for example in the pile cap excavation work the total duration in the Pile cap excavation package is 7 days/pier x 20 Pier (Total Pier) = 140 days, of the total duration the work shows that the duration of each job varies so that the duration of each job varies so that the success of the succor is scheduled from the end of the predecessor work [24], so it uses the logic of finishing to finish, whereas if the successor is slower after the first item of predecessor (predecessor)) completed then this uses the logic of the Start to Start dependency, for example pile cap excavation work and pile cap casting is a successor that is faster than the predecessor is pile cap excavation work on day 104 so that the pile cap casting work will end after the cycle 7 days later or on the 146th day and anything for all items is shown in Table-9.

Table-9. Schedule of LoBs on LRT projects.

No	Activity	Duration of Perception (Day)	Total 20 Pier Duration (Day)	Start Package	Finish Package
1	Excavation Pile cap	5	100	0	100
2	Concreting pile cap	6	120	5	125
3	Concreting Pier phase 1	5	100	11	111
4	Concreting Pier phase 2	9	180	16	196
5	Concreting Pier phase 3	11	260	25	285

In the calculation of Table-9 above, it is estimated that the completion time for one pier is 65 days which is in pier phase 3 (50 + 15) casting which is on day 65. The delivery rate for each subsequent pier is every 15 days thereafter.

So the total duration of completion of 20 piers is 350 days. From Figure-10 above that seen The LOB diagram on the LRT development project. it can be seen that there is no work that intersects or conflicts with each other but there is a Buffer [11] Time between pile cap excavation and pier phase 1 casting with a relatively long time so it needs to be repaired for its duration, to get the ideal duration results. Following are improvements in LoB on the LRT Project:

Alternative

In this alternative, researchers will try to reduce the duration of each work minus 2 days from the normal duration excludes concreting pile cap. Based on the calculation of Table-10 above, it can be estimated that the completion time for each work cycle duration is reduced by 2 days in pile cap excavation work, pile cap casting, pier phase 1 casting, pier phase 2 casting, pier phase casting 3. For example, for pile casting work stamp (11 + 25 days) total duration to 36 days. So the total duration is 285 days.

From Figure-11 it can be seen that the buffer time has been summarized so that the project completion time becomes more advanced for 49 days which at the time of completion of the project completion is on day 334 after the buffer time summation of the work duration becomes 285 days.

Critical path method (CPM)

In the process of using the CPM method, the researcher will determine the type of activity and duration

Table-10. Schedule LoB after improvements.

No	Activity	Duration of Perception (Day)	Total 20 Pier Duration (Day)	Start Package	Finish Package
1	Excavation Pile cap	7	140	0	140
2	Concreting pile cap	6	120	26	146
3	Concreting Pier phase 1	7	140	32	172
4	Concreting Pier phase 2	11	220	39	259
5	Concreting Pier phase 3	15	300	50	350

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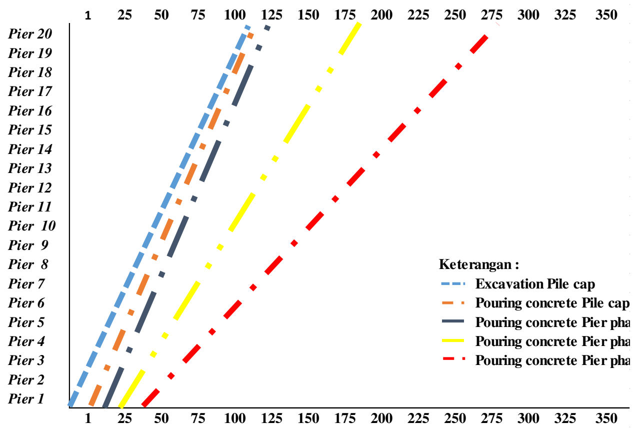

Figure-9. LoB diagram on the LRT project.

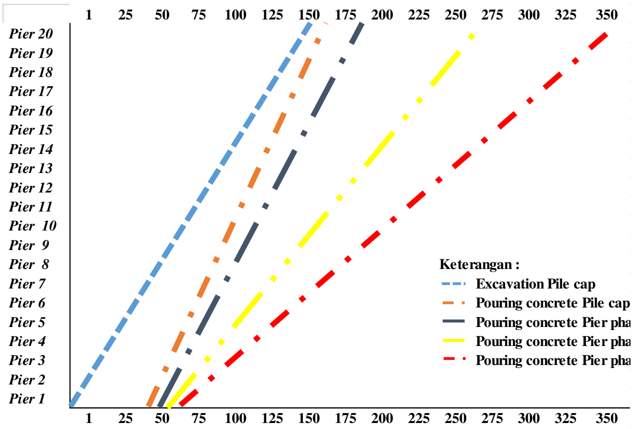

Figure-10. Alternative 1 LoB diagram.

of work [22] as in Table-11, we can see an example for pier 01 and pier 02 that the duration of each item's work and also the relationship between predecessor and successor.

Table-11. Types of activities and duration of work.

No	Activity	Code	Durasi	Predecessor	Succesor
1	Pier 1	P1	36		P4
2	Pier 2	P2	36		P5
3	Pier 3	P3	36		P6
4	Pier 4	P4	36	P1	P7
5	Pier 5	P5	36	P2	P8
6	Pier 6	P6	36	P3	P9
7	Pier 7	P7	36	P4	P10
8	Pier 8	P8	36	P5	P11
9	Pier 9	P9	36	P6	P12
10	Pier 10	P10	36	P7	P13
11	Pier 11	P11	36	P8	P14
12	Pier 12	P12	36	P9	P15
13	Pier 13	P13	36	P10	P16
14	Pier 14	P14	36	P11	P17
15	Pier 15	P15	36	P12	P18
16	Pier 16	P16	36	P13	P19
17	Pier 17	P17	36	P14	P20
18	Pier 18	P18	36	P15	
19	Pier 19	P19	36	P16	
20	Pier 20	P20	36	P17	

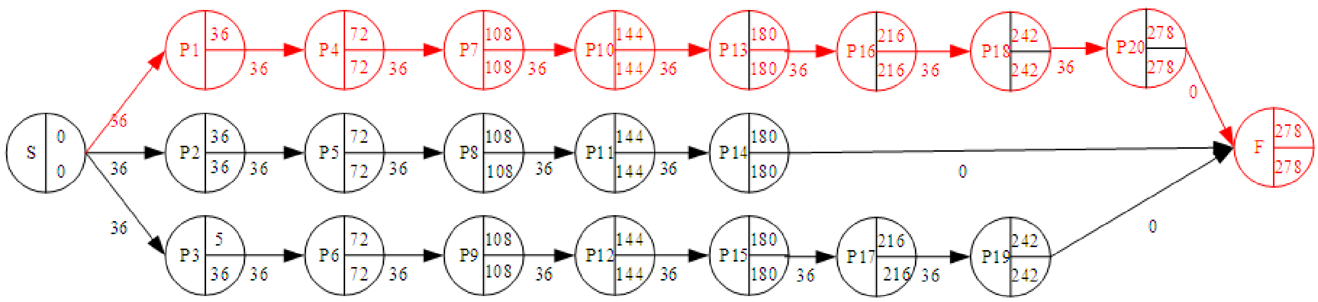

Figure-11. AON diagam.

From Table-10 above it can be analyzed the critical path whit AON Diagram in this work, as shown in Figure-11.

CONCLUSIONS

From the results of statistical analysis research and the validation of case studies on Multi-Span Bridge-based light railroad construction projects it can be collected, among others:

a) The relationship between variables scheduling, productivity and design, and management of resources and external has a correlation with the project time performance variables.

b) The following are ten dominant factors in optimizing project time performance based on the integration of the Line of Balance method and the Critical Path Method:

- Logical relationships between activities
- Time butter
- Analysis of resources
- Determination of critical paths
- Job analysis
- Analysis of labor requirements
- Project time optimization
- Analysis of repetitive work
- Analyze the schedule of each work unit
- Project manager experience

c) From the case study, the application of the Line of Balance method can optimize the duration of work from 334 days to 285 by reducing the buffer time

d) From the results of the research, the application of the integration of Line of Balance and Critical Path Method on light railroad development projects can result in optimization of project time performance by reducing schedule 16.77%.

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