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CYCLONE Modeling Analysis Operation Slab Work Project Conggeang Bridge – Cisumdawu Toll Road Section 5A

Dhean Dwi Lestari[1*], Denny Alfianto[2], Yusfiansyah Insan Rosidi[3]
[1,2,3]Institut Teknologi Bandung, Bandung, West Java, Indonesia
E-mail: 25022020@mahasiswa.itb.ac.id[1], 25022014@mahasiswa.itb.ac.id[2], 15019009@mahasiswa.itb.ac.id[3]

Abstract

Construction productivity measures the output generated in the construction process using available resources. In the Indonesian Construction Industry, construction is often carried out inefficiently, resulting in high construction costs, prolonged durations, and substantial waste, leading to low levels of construction productivity. This study aims to enhance construction effectiveness through planning and management aided by model simulations, specifically targeting slab work operations at the Conggeang Bridge Project - Cisumdawu Toll Road Section 5A. The modeling simulation in this study utilizes the CYCLONE model with the assistance of EZSTROBE/STROBOSCOPE and SIMULINK software. This approach provides data on productivity, utilization factor, and average wait time for the operations under review. Based on the obtained data, a productivity and sensitivity analysis is conducted to identify several alternative improvements in the execution of slab work operations on this bridge. The proposed improvements aim to reduce construction costs, implementation duration, and generated waste, thereby increasing overall construction productivity.

Keywords: Construction, Productivity, Construction Operation, CYCLONE, EZSTROBE, SIMULINK.

INTRODUCTION

Currently, the Indonesian construction industry and various parts of the world are still experiencing inefficiencies in the implementation of the construction process (Choi et al., 2016). There is still too much waste in the form of activities that use resources but do not produce the expected value (Thürer et al., 2017). Based on data from the Lean Construction Institute, waste in the construction industry is around 57%, while activities that provide added value are only 10%. Waste can be in the form of activities that use resources but do not produce the expected value (value), such as excessive production, imperfect products produced, unnecessary movement of people or materials, and so on (Suardi et al., 2018).

The amount of waste that occurs in the construction process is a problem that needs special attention from construction actors because this will impact the use of time & space during the construction process, which also impacts the cost of completing the project. One of the solutions offered in reducing waste in the construction process is to increase productivity; this is because productivity can be used as a parameter in determining inefficiency & efficiency during the implementation of the construction process. Productivity that has a high value shows the greater the profit obtained by the contractor (Fulford & Standing, 2014).

In this study, we will analyze the Conggeang – Cisumdawu Bridge Project Section 5A. The operation to be analyzed in this project is slab work. The selection of slab work is because this operation is one of the operations that affects the implementation of the bridge (Xiang et al., 2022). So, it is hoped that the modeling in this operation will increase construction productivity in the bridge project.

This study aims to simulate slab operations, conduct productivity and sensitivity analysis based on modeling carried out on slab operations, and provide alternative solutions for slab operations based on productivity levels, utilization factors, and average time waits.

METHODS

This research begins by determining the research background, identifying problems, and formulating goals. Furthermore, a literature review was carried out regarding the problems raised. The next stage is the collection of the required data. After the data is collected, it is continued at the CYCLONE modeling and model simulation stage using software. In this stage, the data is analyzed to determine the CYCLONE model according to the conditions in the field, which will then be simulated with the help of Simulink and Stroboscope software. After the simulation is successful, the stage continues by conducting a sensitivity analysis that is expected to result from the software and sensitivity analysis to be able to provide productivity values as well as solutions, alternatives, or recommendations for a construction operating system (Negahban & Smith, 2014).

RESULTS AND DISCUSSION

Operations Modeling

Assumptions Used

The modeling of slab work in this study was carried out based on the following assumptions: the cycle for modeling slab work was measured based on 1 span of bridge, which requires 2 bondek trucks, 8 rebar trucks, 2 formwork trucks, and 22 mixer trucks to meet the volume of 1 span of 127.5 m^3. It is also assumed that the laborer resources are already in the form of a team of 3 people.

Identify the Duration and Resource Work Task

Work tasks in CYCLONE modeling are tasks or work that need to be done in the modeling that is carried out (Nataadiningrat et al., 2020). Before modeling CYCLONE with the help of

EZSTROBE and SIMULINK, it is necessary to identify the duration of each work task in CYCLONE modeling. The duration in this modeling uses triangular and deterministic distributions (Hajdu & Bokor, 2016). Triangular distribution is a duration distribution based on an approach that assumes that the duration of an indeterminate activity can be estimated using three parameters, namely: minimum duration (a), maximum duration (b), and realistic duration (M). A deterministic distribution is a duration distribution that uses a definite or fixed time estimation approach.

In addition, before modeling CYCLONE, it is necessary to identify the resources that will be used in slab modeling (Yoo et al., 2024). These resources include materials, tools, and workers. The following is the identification of the duration and resources of the slab operation's modeling.

Table 1. Duration and Resource Work Task

ID	Work Task	PDF	Duration			Resource	Quantity
			a	m	b		
WT 1	Load Bondex to Truck on Supplier	Deterministic		20		Bondex Truck 1 (Bondex)	1 2
WT 2	Travel Bondex to Stockyard	Triangular	30	45	50	Truck 1 (Bondex)	2
WT 3	Unload Bondex to Stockyard	Deterministic		20		Laborer Truck 1 (Bondex)	2 2
WT 4	Truck Return to Load Bondex	Triangular	30	45	50	Truck 1 (Bondex)	2
WT 5	Move Bondex to Site	Triangular	7	10	15	Bondex Truck 2 (Bondex)	1 2
WT 6	Load Bondex to Winch	Deterministic		10		Bondex Crane Space	1 1 2
WT 7	Lifting Bondex to Bridge	Deterministic		10		Crane	1
WT 8	Remove Bondex from Winch	Deterministic		10		Laborer Crane	4 1
WT 9	Install Bondex	Triangular	150	200	250	Laborer Bondex	4 1
WT 10	Load Iron to Truck on Supplier	Triangular	5	10	15	Iron Truck 1 (Iron)	1 8
WT 11	Travel Iron to Stockyard	Triangular	10	15	20	Truck 1 (Iron)	8
WT 12	Unload Iron to Stockyard	Triangular	5	10	15	Laborer A Truck 1 (Iron)	1 8
WT 13	Truck Return to Load Iron	Triangular	10	15	20	Truck 1 (Iron)	8

WT 14	Barbending	Triangular	180	240	270	Iron Laborer A	1 1
WT 15	Load Iron to Truck on Stockyard	Triangular	5	10	15	Iron Hydraulic Truck 2 (Iron)	1 1 2
WT 16	Travel Iron to Site	Triangular	5	10	15	Truck 2 (Iron)	2
WT 17	Load Iron to Crane	Triangular	5	10	15	Crane Truck 2 (Iron)	1 2
WT 18	Truck return to Stockyard	Deterministic		10		Truck 2 (Iron)	2
WT 19	Install Iron	Triangular	180	240	300	Laborer C Iron	1 1
WT 20	Load Formwork Material to Truck on Supplier	Triangular	7	15	20	Formwork Truck 1 (Bekisting)	1 2
WT 21	Travel Formwork Material to Stockyard	Triangular	20	30	45	Truck 1 (Bekisting)	2
WT 22	Unload Formwork Material to Stockyard	Triangular	10	20	30	Laborer A Truck 1 (Bekisting)	1 2
WT 23	Truck Return to Load Formwork Material	Triangular	20	30	45	Truck 1 (Bekisting)	2
WT 24	Formwork Fabrication	Triangular	180	240	300	Formwork Laborer A	1 2
WT 25	Load Formwork to Truck on Stockyard	Triangular	20	30	40	Formwork Laborer A Hydraulic Truck 1 (Bekisting)	1 1 1 2
WT 26	Travel Formwork to Site	Deterministic		7		Truck 1(Bekisting)	2
WT 27	Lifting Formwork to Bridge	Deterministic		15		Truck 1(Bekisting) Laborer B Crane	2 1 1
WT 28	Install Formwork	Triangular	200	260	320	Formwork Laborer B	1 1
WT 29	Load Concrete to Truck on Batching Plant	Deterministic		20		Concrete Truck 1 (Concrete)	1 7
WT 30	Travel Concrete to Site	Triangular	30	45	60	Truck 1 (Concrete)	7
WT 31	Maneuver to Position to Dump Concrete	Deterministic		10		Avail Post Truck 1 (Concrete)	2 7

WT 32	Dump Concrete	Triangular	20	25	30	Hooper Truck 1 (Concrete)	1 7
WT 33	Position Depart	Deterministic		10		Truck 1 (Concrete)	7
WT 34	Truck Return to Batching Plant	Triangular	30	45	60	Truck 1 (Concrete)	7
WT 35	Concrete Pumping	Deterministic		15		Hooper Truck 1 (Concrete)	1 7
WT 36	Slab Casting	Triangular	30	60	120	Laborer	2

CYCLONE Modeling

CYCLONE modeling or simulation in construction operations analysis is the process of using mathematical or computer tools and techniques to replicate and predict the performance and outcomes of construction projects (Dabirian et al., 2016). The purpose of such modeling is to understand how the project will run, identify potential problems or risks, and find the optimal solution or strategy to implement in the project (Virine & Trumper, 2019). In this study, CYCLONE modeling for slab work operations is carried out per cycle, where each cycle consists of bonded installation, ironing, formwork, and casting. For one cycle of CYCLONE is calculated for 1 span. The following in Figure 3 is the CYCLONE modeling carried out in the operation of the Conggeang Bridge Slab Work Project – Cisumdawu Toll Road Section 5A. For CYCLONE modeling, every work in the slab operation runs simultaneously (continuously) until it produces an output from the operation, namely the slab for one bridge span (Gazzola, 2015). Then for CYCLONE modeling, each work can be seen in **Appendix A: CYCLONE Modeling of the Conggeang Bridge Project.**

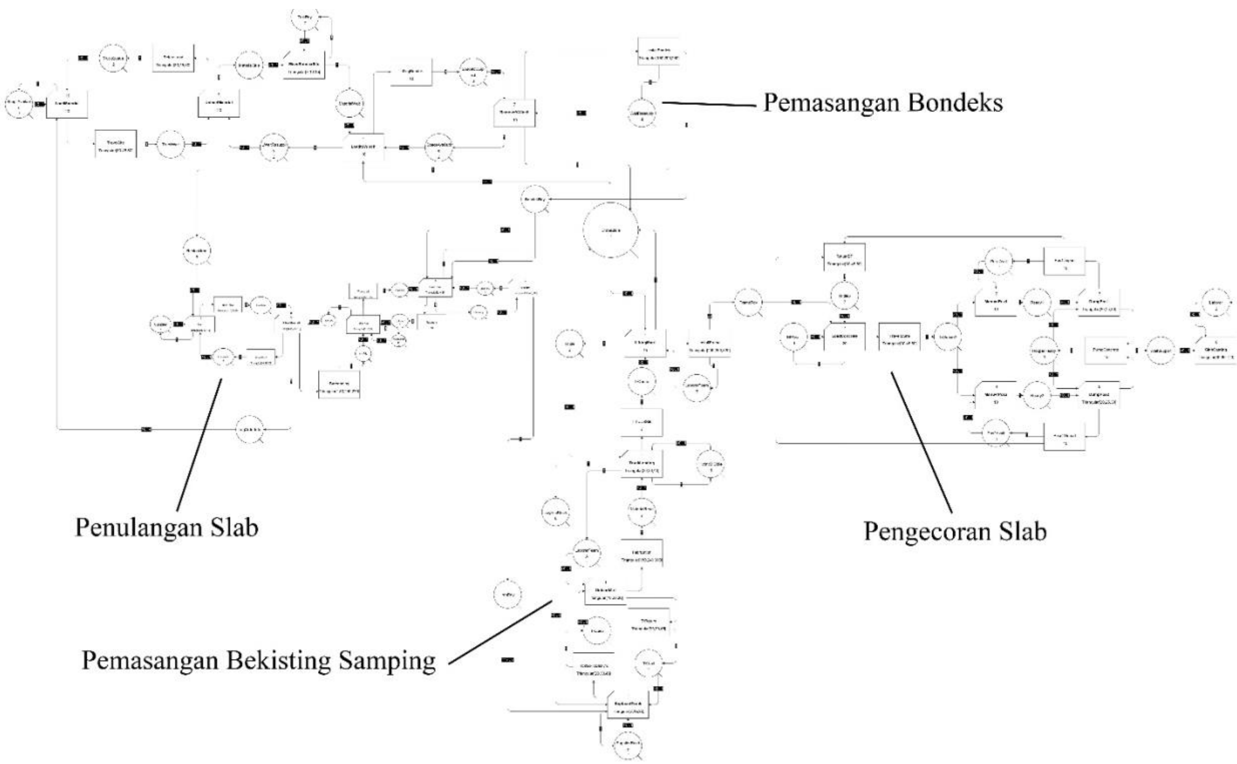

Figure 1. CYCLONE Operation Slab Work of Conggeang Bridge Project

Analysis of Simulation Results

This study simulates several cycles to get productivity where the simulation produces a relatively small productivity variation over time. The productivity value obtained is productivity for one span (one cycle) (Kaushal et al., 2017). Simulations were carried out using SIMULINK and EZSTROBE/STROBOSCOPE.

EZSTROBE Result Analysis

In the simulation using EZSTROBE software, the value of the time required in 1 cycle (1 cycle = 1 span) was obtained as 6231.22 minutes or 103.853 hours. Based on this value, the productivity value of the cycle can be determined using the formula below (Cheng et al., 2017).

$$produktivitas = \frac{jumlah\ unit}{jumlah\ jam}$$

$$produktivitas = \frac{1}{103{,}8537} = 0{,}00963\ {}^{unit}/_{jam}$$

Based on the calculation above, it can be known that the productivity value of slab work for each span is 0.00963 with the time of each cycle is 103.853 hours. In addition, this slab work consists of 15 spans so the total time needed to complete the entire slab work is 1557,805 hours or 64.9 days. The following has been included the data from the model test using EZSTROBE software in ${}^{unit}/_{jam}$**Appendix B: EZSTROBE Analysis Results**

Analysis of SIMULINK Simulation Results

In the simulation using SIMULINK software, the value of the time required in 15 spans (1 cycle = 1 span) is obtained of 74273 minutes or 1237.88 hours so that the time per cycle can be obtained by dividing the total time by the number of spans (15), which is 82.5255 hours. Based on this value, the productivity value of the cycle can be determined using the formula below.

$$produktivitas = \frac{jumlah\ unit}{jumlah\ jam}$$

$$produktivitas = \frac{1}{82{,}5255} = 0{,}01211\ {}^{unit}/_{jam}$$

Based on the calculation above, it can be known that the productivity value of slab work for per span is 0.01211 with the time of each cycle is 82.55 hours. In this slab work consists of 15 spans so the total time needed to complete the entire slab work is 1237.88 hours or 52 days. Here is a graph regarding the productivity & cycle time of slab work. ${}^{unit}/_{jam}$

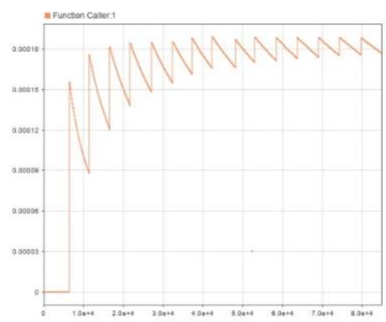

Figure 2. Slab Job Productivity

From the graph of the Simulink simulation results, you can see the productivity value.

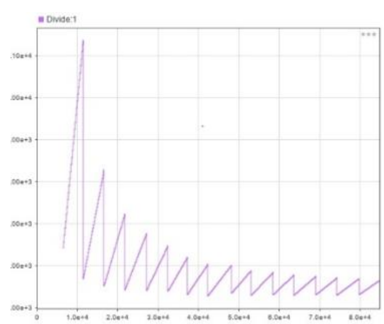

Figure 3. Slab Job Cycle Time

In addition to productivity & cycle time, there are other indicators in SIMULINK used in this study, namely:

1. Resource utilization useful for determining the intensity of the use of resources involved in the process

2. Resource average wait (idle time), useful for knowing the wait time of the resources involved in the process

Here is a combined graph of the resource utilization and idle time of the 4 processes on the slab job. The graph of resource utilization and idle time for each bondex installation, slab repetition, side formwork installation, and slab casting work is found in **Appendix C: SIMULINK Analysis Results.**

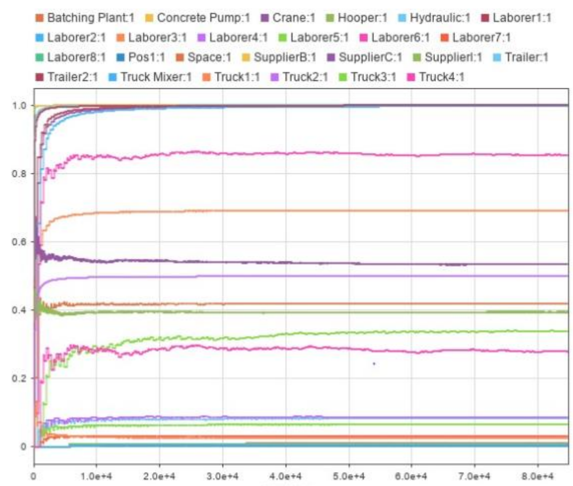

Figure 4. Resource Utilization Slab Work

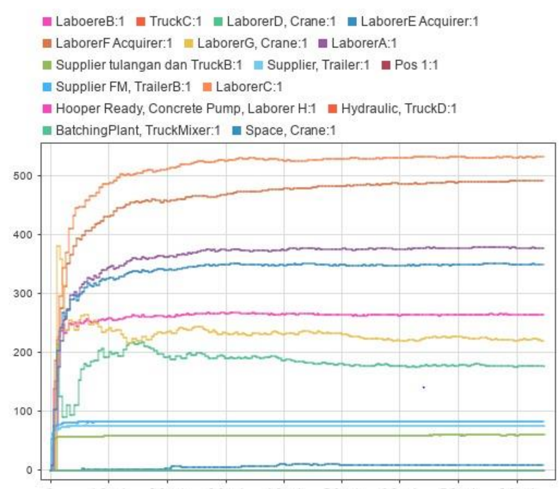

Figure 5. Average Wait Resources Slab Jobs

Bondek Installation

In the resource utilization graph, it can be seen that there are several resources in the Bondek installation process that have a resource utilization value below 0.5 (Hahnel et al., 2021). This shows that the use of these resources is not efficient. In addition, some resources that have a value of 1, it can be re-optimized by increasing the number of resources so that the construction process runs more effectively (Dehghanimohammadabadi et al., 2017). Meanwhile, in the average wait of resource charts, it can be known the idle time of each resource involved in the bondex installation process, where in this case, it can be seen that the waiting time of each resource begins to stabilize after entering the 30,000th minute and it is also known that space & crane resources have the largest waiting time among other resources.

Slab Ironing

In the resource utilization graph, it can be seen that there are several resources in the slab ironing process that have a resource utilization value below 0.5, such as laborer 4 & truck 3. This shows that the use of these two resources is not efficient. In addition, some resources with a value of 1 can be re-optimized by increasing the number of resources so that the construction process runs more effectively (Dasović & Klanšek, 2021). Meanwhile, in the average resource wait graph, the idle time of each resource involved in the ironing process can be known. The resource that has the longest idle is Laborer Team C. The waiting time of each resource starts to stabilize when entering the 30,000-minute mark

Installation of Side Formwork Slab

In the resource utilization graph, it can be seen that the indication of resource utilization begins to stabilize when entering the 20000 minutes (Yan et al., 2020). There are several resources in the process of installing side formwork with a resource utilization value below 0.5 such as hydraulic, laborer7, & truck4. This shows that the use of these three resources is not efficient. In addition, resources that have a value of 1 can be re-optimized by increasing the number of resources so that the construction process runs more effectively. Meanwhile, in the average wait resource graph, it can be known the idle time of each resource involved in the side formwork installation process, where in this case, it is known that laborer4 resources have the largest waiting time among other resources and hydraulic, which has a value of 0 which means there is no waiting time and it can be said that the resources work throughout the cycle.

Slab Casting

In the resource utilization graph, it can be seen that the indication of resource utilization starts to stabilize when entering the 30000th minute and it is known that resources pos1 has the smallest utilization value compared to other resources. This shows that these resources have the lowest efficiency so it is necessary to re-plan the number of resources (Akbarzadeh et al., 2019). Meanwhile, in the average wait resource chart, it can be seen that the idle time of all resources in the slab casting process is 0, which means that all resources do not have idle time and it can be said that these resources work throughout the cycle.

Comparison of Simulation Productivity with Field Data

The following is the result of comparing data on productivity & cycle time in modeling in EZSTROBE & SIMULINK software with the reality in the field from January-March (75 days).

Table 2. Comparison of Simulation Results with Field Comparison

Category	EZSTROBE	SIMULINK	Field
Productivity	0,00963	0,01211	0,0083
Cycle Time	103,853	82,52	120

From the table, it can be seen that the productivity of the simulation results using ezstrobe and Simulink is different from the field data. This can be because, in the field, there are still holidays or non-working days, but they are still included in the total number of days of slab work.

Sensitivity Analysis

Sensitivity Analysis is the process of understanding and evaluating the impact of changes in certain variables on the system (Pang et al., 2020). It is carried out using Simulink Software. The combination of improvements can be seen in the following table to test the sensitivity of each resource (Sinha & Chandel, 2014).

Table 3. CYCLONE Sensitivity Analysis Operation Slab Work Conggeang Bridge Project

	Existing Conditions			Iteration 1			Iteration 2			Iteration 3		
Resource	**Sum**	**Utilization**	**Average Wait (Min)**	**Sum**	**Utilization**	**Average Wait (Min)**	**Sum**	**Utilization**	**Average Wait (Min)**	**Sum**	**Utilization**	**Average Wait (Min)**
Supplier bondex	1	39.4%	76.04		100.0%	60.2	1	100.0%	60.2	1	100.0%	60.2
Bondex trailer	2	100.0%	76.04	4	100.0%	60.2	5	80.0%	60.2	5	80.0%	60.2
Labor Team A	1	100.0%	378.9	2	100.0%	345.8	2	100.0%	345.8	2	100.0%	345.8
Labor Team B	1	100.0%	264.9	2	100.0%	229.5	2	100.0%	229.5	2	100.0%	229.5
Supplier Iron	1	100.0%	59.92	1	100.0%	59.92	1	100.0%	59.92	1	100.0%	59.92
Truck B	8	50.0%	59.92	8	50.0%	59.92	16	25.0%	59.92	16	25.0%	59.92
Labor Team C	3	69.2%	531.3	4	51.9%	531.3	4	51.9%	531.3	4	51.9%	531.3
Labor Team D	1	8.5%	180	2	4.3%	173	2	4.3%	173	2	4.3%	173

Labor Team E	2	33.7%	8.8	3	22.2%	13.1	3	22.2%	13.1	3	22.2%	13.1
Supplier Formwork	1	53.4%	83.82	1	53.4%	83.82	1	100.0%	83.82	1	100.0%	83.82
Trailer Formwork	2	100.0%	83.82	2	100.0%	83.82	4	100.0%	83.82	4	100.0%	83.82
Labor Team F	3	85.4%	490.4	4	63.2%	489.8	4	63.2%	489.8	4	63.2%	489.8
Labor Team G	2	3.2%	225.3	3	2.1%	203.6	3	2.1%	203.6	3	2.1%	203.6
Batching Plan	1	8.3%	0	1	8.3%	0	1	8.3%	0	2	9.1%	0
Concrete Pump	1	97.00%	0	1	96.00%	0	1	97.00%	0	1	97.00%	0
Truck Mixer	22	86.15%	0	22	86.15%	0	22	86.15%	0	24	86.15%	0
Productivity	0.00021542			0.00021552			0.00022552			0.00022752		
Cycle Time	4621			4611			4530			4421		
Duration of Work	74273			74251			74251			72174		

Based on the table above, it can be seen that after making improvements using sensitivity analysis, the productivity value increases and the cycle time decreases, but the results of the improvement have results that are not much different from the existing conditions. From the table above, it can also be concluded that iteration 3 is the best iteration to increase productivity.

CONCLUSION

The CYCLONE modeling results are presented in Figure 3, and Appendix A. Productivity outcomes for Slab Work Operations using EZSTROBE software were found to be 0.00963 units per hour, while SIMULINK yielded 0.0106 units per hour. The third iteration offers the best combination of improvement based on sensitivity analysis regarding optimal resource combinations and modeled productivity. This has the potential to enhance productivity values from current conditions and reduce cycle times.

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