Lean Construction Based Tower Crane Requirement Optimization In High Rise Building Construction Project

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ABSTRACT

Fueled by the growth of residential needs, high rise building projects has become a major contributing segment that increases the competition in the world of construction project services. The problem that often occurred on the use of construction service is concerning its project management, which if described thoroughly is the construction project's resource allocations. Tower crane as a heavy equipment holds a crucial part in determining the project's cost and duration efficiency level. The method used to determine the amount of tower crane in this research is lean construction. Lean construction is a method used to design a product in a way to minimize waste, shorten its duration, and an attempt to reach the maximum values. The lean construction application suggested 2 new layouts to be simulated, with the first alternative resulting in 1.92% of cost efficiency and 5.54% of cost efficiency and the second alternative resulting in 3.85% of cost efficiency and 36.37% of time efficiency, therefore effective in minimizing waste.

Keywords Efficiency; high rise building; lean construction; tower crane

I. INTRODUCTION

Fueled by the growth of residential needs, high rise building projects has become a major contributing segment that increases the competition in the world of construction project services. In the execution of massive construction projects, including high rise building, the needs of materials and its supporting types of equipment are considerably high (Husin et al. 2015). The main supporting equipment used in the construction of high rise buildings are tower crane, mobile crane, concrete pump, and excavator. Tower crane as the major heavy equipment functions as the means of materials movement and transportation from one place to another in a construction project is a very prominent heavy equipment in every condition of a high rise building construction project, including high and small area projects (Lu 2015). Further elaborated, its function is closer to a vertical-horizontal mobilization equipment that aids the structural activities of a high rise building construction project. Important considerations regarding capacity, operational method, and cost must be discussed in order to choose which equipments suit the project best.

The problem that often occurred on the use of construction service is concerning its project management, which if described thoroughly is the construction project's resource allocations. Construction types of equipment are the most crucial resource and the one that requires major investation. A good resource allocation will determine the effectiveness of the equipment's utilization (Alarcon, Venegas, and Campero 1994). In this research, the determination of the amount of the construction equipment needed would be based on the consideration of its location in order to achieve the optimal amount. After the optimal amount of equipment needed has been acquired, the result of the experiment would be further analyzed and tested to see its effect in decreasing the overall project cost and duration in order to achieving the aim of a sustainable work (Koskela 1992).

Tower crane as a heavy equipment holds a crucial part in determining the project's cost and duration efficiency level. The election of the type oftower crane that would be used are based on its utilization, meaning every variable connected to its utilization should be inspected thoroughly in order to achieve the best choice which leads to lower project cost and duration.

The method used to determine the amount of tower crane in this research is lean construction. Indonesia's construction industry and the construction industry in general still suffers of inefficiency problems in its execution. There are still a lot of waste in the form of activities that employ resources but adds no expected value. In figure 1., the data served by the Lean Construction Institute implies the waste made in construction industry reached 57% while the value adding activities is only 10% (Abduh and Roza 2006).

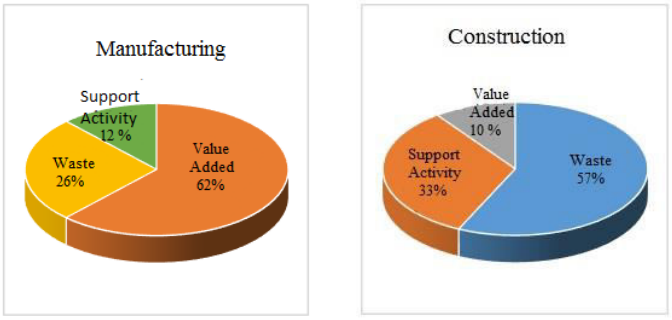

Figure 1. The proportion of waste in the construction and manufacturing industry
Source: Abduh (2006).

2. METHODS

The designed scheme and flow of the research could be observed in figure 2, which also explains in which case and phase should lean construction be used. Lean construction should only be used when the utilization of the tower cranes does not reach 90%.

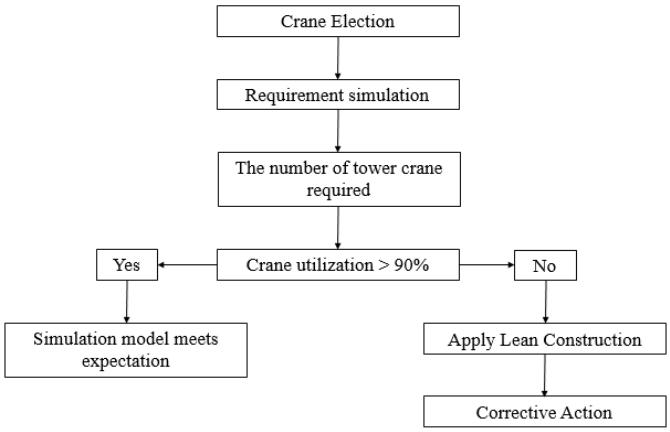

Figure 2. Research flow chart

2.1. Data Collection

The data collection process of this research utilized the observational method, whereas on site research and observation would be carried out directly in order to acquire the required data regarding the utilization of tower crane in high rise building construction. The project site used in this research was a construction of an apartment and hotel located in Grogol, Jakarta Barat.

The data anaylisis and processing phase consists of :

a) The primary data for this research was acquired by directly monitoring and observing on site data which includes the location of the construction work, the heavy equipments used, and the operational cycle. The primary data includes the type of the crane used, the operational time of the tower crane, and the type and quantity of the materials used.
b) The secondary data for this research was acquired from the existing data that was collected by other parties, in this case, the construction company. The acquired data was used to draw the connection between the outcome of this research to the cost and duration of the project. The secondary data used in this research include the project's site plan, the work volume data, and the tower crane's rent cost data.

2.2. Lean Construction

According to the recent study, lean construction is a method used to design a product in a way to minimize waste, shorten its duration, and an attempt to reach the maximum values(Abduh 2007). The principals of lean construction are :

a) Eliminate waste
b) Precisely specify the value from the perspective of the ultimate customer
c) Clearly identify the process that delivers what the customer value (the value stream) and eliminate all non-value adding steps
d) Guarding leftovers materials/components against insolvency of the next action steps
e) Making the product when it is needed and in the shortest duration
f) Increasing the product qualities with continuous upgrades

The benefit of lean construction method has been shown with the increasing achievement of many construction projects from its every activity steps. Lean construction may require more time at the design and planning phase, but the more attention given at this step would later minimize or eliminate the occurrence of conflicts that could dramatically alter the project's cost and duration (Lean et al. 2008).

The main purpose of lean production, in this case lean construction, is to minimalize yhe production cost in order to increase the competitiveness with the market. The main characteristic of lean construction is the elimination of waste contionously to increase the construction performance and customer satisfaction. In short, lean construction could be concluded as a paradigm that focused itself to

increase efficiency with a whole new approach (Budny, McCrea, and Szymanski 1995).

The distinctive feature of lean construction includes a clear goal of the delivery system in order to maximize the operational performance on the project level along with the design process of the product and the application of production control from the design and planning stage to the delivery stage (Howell and Ballard 1998).

2.3. Tower Crane

Tower crane is the most used type of crane used in the construction of high rise buildings. In addition to its use on the construction of high rise buildings, the tower crane is also used on bridge constructions. Tower crane is categorized into fixed crane segment, which means it could not be moved easily from one fixed location to the other. When the construction project starts, the crane would be brought to the project location with a specialized armada, then it would be constructed and erected on the site. After its utilization in the project is done, then the crane would be taken apart to be transported.

In the world of construction, industrialization improves the construction process. The centrality of tower crane in determining the project's overall productivity puts material movement and transportation into a very crucial spot in establishing the project's overall productivity (Shapira, Lucko, and Schexnayder 2007)Even in an intensive lifting schedule, the crane may not be used in its maximum potential due to the inaccuracy of its utilization calculation that leads to the crane being ineffective in aiding the project's efficiency. Therefore, shortening the crane's rotation per time unit must not be overlooked and monitored intensely to increase productivity (Rosenfeld and Shapira 1998)

Further elaborated, its function is closer to a vertical-horizontal mobilization equipment that aids the structural activities of a high rise building construction project. Every type of tower crane has its own characteristic and base specification that each suits a spesific utilization demand. The tower crane must be elected to suits the need of the project because the wrong election would cause further problems and safety concerns.
Considerations when electing tower crane includes :

1. Type of tower crane
2. Lifting capacity
3. Jib length and reach
4. Site location and geographical condition

2.4 Lean Construction based Tower Crane Simulation

The original layout of the 2 single jib tower crane used in the project could be observed in figure 2. The implementation of lean construction principles suggested that there are 2 factors that need to be analyzed regarding the operation of the tower crane which is the loading or lifting capacity of the tower crane against the materials quantity and the efficiency of the tower crane's position. Modifying the original layout in figure 2, 2 simulation models were developed based on the lean construction implementation which is the utilization of 2 single jib cranes with different or same lifting capacity and the utilization of a single or combination of single and double jib cranes. The layout of the simulations done on this research could be observed in figure 4.

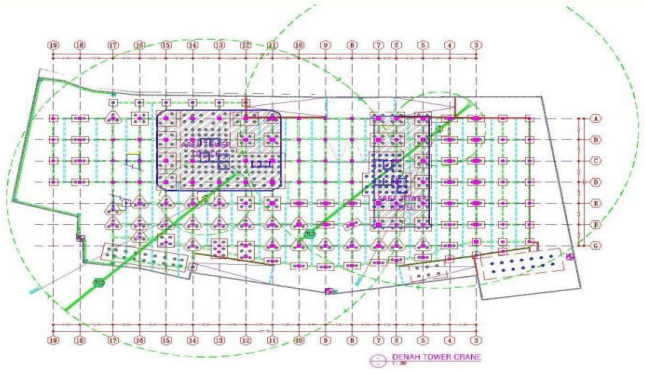

Figure 3. Original tower crane layout

The simulation results would be further referred to the principles of lean construction to determine if the model could be accepted or if there is still a considerable amount of waste occurring.

3. RESULTS AND DISCUSSION

3.1 Tower Crane

3.1.1 Tower crane specifications

The simulation models were tested on 8 floors platform construction in a 24 story apartment and hotel building construction project. The contractors were using 2 tower cranes, which are:

a. TC1 is a product of Construciones Metalica Comansa, SA (Spain) with the capacity of 2 tonnes on its jib end and with the jib length of 60 m.

b. TC2 is a product of Sanj Crane Ltd. (China) with the capacity of 10 tones on its jib end and with the jib length of 59.8 m.

Table 1. TC 1 Load capacity

End	Middle	Base
2000 KG	3500 KG	6000 KG

Tabel 2. TC2 Load capacity

End	Middle	Base
2300 KG	5000 KG	1000 KG

3.1.2 Tower crane lifting observation and layout

The observation of this research was done in one year or 52 weeks. Based on the initial analysis using the tower crane specifications listed in table 1 and table 2 and the data of the quantity of the goods and equipment used, the resulting yearly lifting capacity was 74.256 t. However, further collected site data that was summed up in table 4 indicated that the actual yearly lifting done by the tower cranes was only 60.361 t, which could be translated to a 1.150 t of weekly lifting. This result heavily indicated that a waste occurred, and further analysis regarding the duration of the project suggested that the waste was worth 12 weeks of the project's duration.

ALTERNATIVE 1

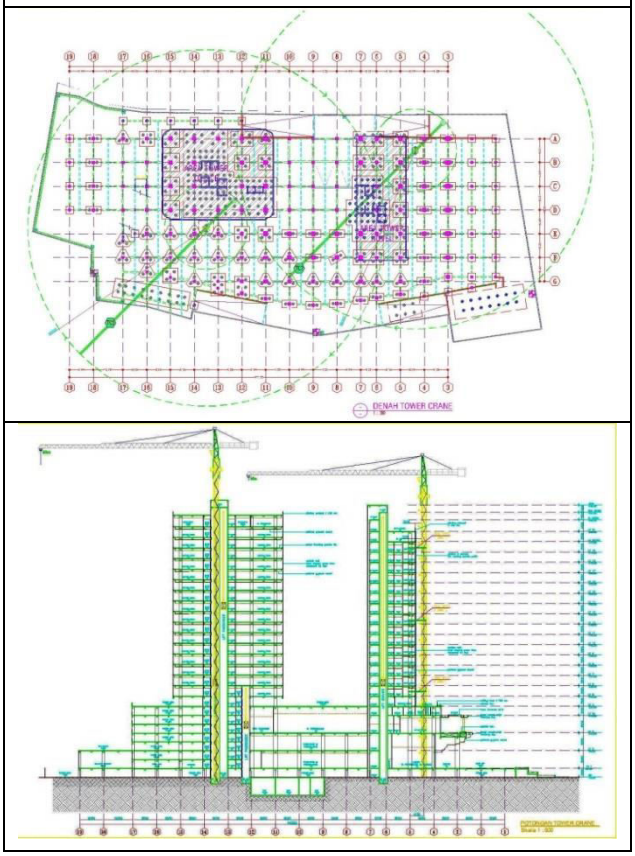

Figure 4. Alternative 1 tower crane layout

Along with the calculation that is elaborated on table 3, it is concluded that the original utilization of 2 single jib cranes only reached 81% of its utilization percentage, which by applying the lean construction rule derived from its principle, did not met the standard of 90% so that it has to undergo the lean construction based simulations so that it may reach the desired percentage.

ALTERNATIVE 2

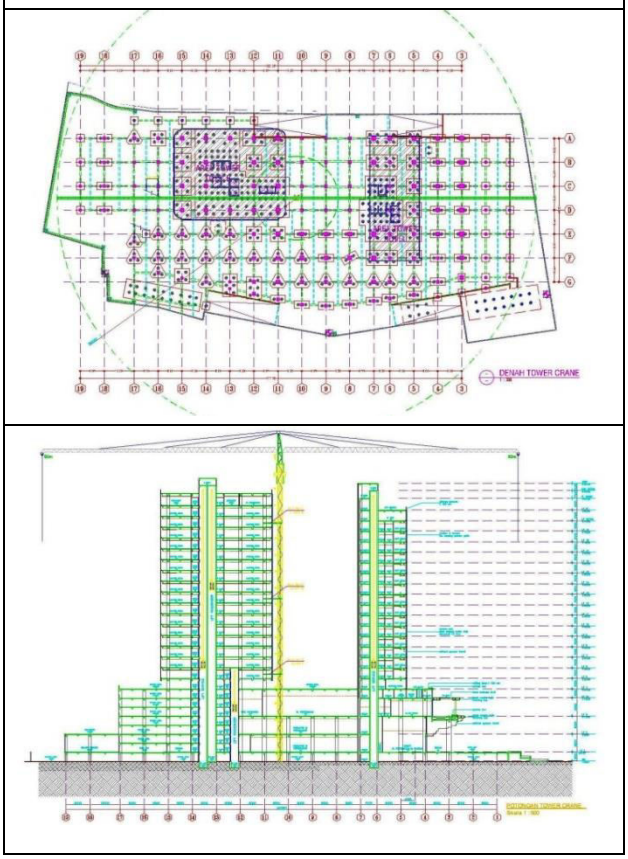

Figure 5. Alternative 2 tower crane layout

3.2 Simulation

Table 3. Crane utilization percentage (existing, alternative 1, alternative 2)

CRANE UTILIZATION PERCENTAGE

DESCRIPTION	AVAILABLE (/day/mnt)	CAPACITY (tone)	CAPACITY / DAY (tone)	REALIZATION (tone)	% OF UTILIZATION
CRANE 1	480	3500	84.00	71.00	85%
CRANE 2	480	5500	120.00	94.84	79%
TOTAL CAPACITY			204.00	165.84	81%
ALTERNATIVE 1					
CRANE 1	480	3500	84.00	82.92	99%
CRANE 2	480	3500	84.00	82.92	99%
TOTAL CAPACITY			168.00	165.84	99%
ALTERNATIVE 2					
CRANE 3	480	6600	158.40	165.84	105%
DOUBLE JIB					
TOTAL CAPACITY			**158.40**	**165.84**	**105%**

In the first phase, the acquired data was used in the simulation consisting of 2 single jib tower cranes with the middle lift capacity of 3500 t. The simulation calculation's results which are elaborated in table 4 concluded that the utilization percentage of this simulation reached 99%, which fulfilled the purposes of the lean construction's application. The further positive effect this simulation gave to the cost and duration performance of the construction project could be observed in table 5.

3.3 Validation

Table 4. Lean construction validation

LEAN CONSTRUCTION VALIDATION				
DESCRIPTION	**CAP/TONE**	**LIFT**	**TOTAL CAP/TONE**	**NOTE**
Crane's lift quantity			25.50	Existing
Materials and equipments quantity			20.73	
PERCENTAGE			81%	
ALTERNATIVE 1				
Crane 1	3.5	3	10.50	Per hour
Crane 2	3.5	3	10.50	Per hour
LIFTING CAPACITY PER HOUR			21.00	Per hour
ALTERNATIVE 2				
Lift capacity				
Double jib	6.6	3.33	22.00	per hour

On the second phase, the acquired data was used in the other simulation consisting of 1 double jib tower crane unit with the middle lifting capacity of 6600 t. The simulation result in table 4 showed that this simulation reached an even higher utilization percentage of 105%, which make this system a much more appealing candidate for the real world scenario. Table 5 exclaimed the significant effect this simulation gave to the cost and duration performance of the construction project, bringing them down 36.37% and 3.85% respectively.

Table 5. Lean construction application analysis

LEAN CONSTRUCTION APPLICATION ANALYSIS						
DESCRIPTION	**PLANNED**	**REALIZATION**	**DEVIATION**			
			DURATION		**COST**	
			Weeks	%	IDR	%
EXISTING (2 TC single jib)						
CRANE 1 (cap. 3,5 T)	52 Weeks	64 Weeks	12	23.00		
	37,500,000 IDR	37,500,000 IDR				
	1,950,000,000 IDR	2,400,000,000 IDR				
CRANE 2 (cap. 5,0T)	52 Weeks	64 Weeks	12	23.00		
	43,425,000 IDR	43,425,000 IDR				
	2,258,100,000 IDR	2,779,200,000 IDR				
	4,208,100,000 IDR	**5,179,200,000 IDR**		**23.08**	**971,000,000**	**23.08**
ALTERNATIVE 1 (2 TC single jib)						
CRANE 1 (cap. 3,5 T)		53 Weeks	1	2.00		
		37,500,000 IDR				
		1,987,500,000 IDR				
CRANE 2 (cap. 3,5T)		53 Weeks	1	2.00		
		37,500,000 IDR				
		1,987,500,000 IDR				
	-	**3,975,000,000 IDR**		**1.92**	**-233,100,000**	**-5.54**
ALTERNATIVE 2 (1 TC double Jib)						
CRANE (cap. 6,6 T)		50 Weeks	- 2			
		53,550,000 IDR				
		2,677,500,000 IDR				
	-	**2,677,500,000 IDR**		**-3.85**	**-1,530,600,000**	**-36.37**

4. CONCLUSION

The conclusion obtained after doing research is:

1. The election and utilization of the existing tower crane layout and type resulted in 23% of waste
2. The lean construction application suggested 2 new layout alternatives be simulated, with the first alternative resulting in 1.92% of cost efficiency and 5.54% of cost efficiency and the second alternative resulting in 3.85% of cost efficiency and 36.37% of time efficiency.
3. Lean construction has been proven to be effective when used in tower crane election and utilization phase in a high rise building construction project.

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