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Factors Affecting the Implementation of Line of Balance (LOB) Scheduling and Building Information Modelling (BIM) on Demolition Work

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ABSTRACT

In Indonesia, demolition work has not acquired special attention. The government has not yet published a standard regulating demolition, even though it has become an urgency for many big cities in Indonesia to execute buildings that have reached the peak of their service life. Thus, very few of the many demolition industry use the proper demolition work rules. Departing from the common need for careful planning to complete a high-rise building demolition project, this study aims to identify the factors affecting the top-down by machine demolition work, using one of scheduling method that is Line of Balance (LOB) and Building Information Modelling (BIM) commonly used as engineering software design. It was done by distributing a number of questionnaires to engineers involved in the demolition project of high-rise buildings. Data were analysed using statistical tools to rank design factors on top-down by machine dismantling. It is indicated that buffer time analysis - worker and equipment waiting time, design optimization, project time optimization, work methods (demolition flow), waste management, heavy equipment demand analysis, effective coordination between construction service actors, competent Human Resources (HR) and Job complexity is the top ten factor in top-down by machine demolition work with time considerations. Finally, by identifying the factors affecting the top-down by machine demolition work, it will become a bit of knowledge for further exploration to get streamlined demolition work.

Keywords: Key Success Factors, Demolition, Top-Down by Machine, High Rise Building, Line of Balance (LOB), Building Information Modelling (BIM)

INTRODUCTION

In the life cycle of building, it goes through several phases, until finally the building reaches the peak of its service life and is not recommended for rejuvenating or doing reinforcement. So that in this cycle, the building needs to be demolished. Equal to build a building, demolition work also requires careful planning, and time control is very important. This study will discuss the top-down by machine demolition work. Since the top-down demolition work is the proper demolition method to be applied in the city of Jakarta and other big cities in Indonesia. Taking into consideration the application capabilities in various types of building parts and also the operating characteristics. While in project scheduling that has repetitive activities, the popular scheduling method used is Line of balance (LOB), such as for repetitive demolition jobs. Crushing the structures that tend to be designed typically from top to bottom. And BIM exists as a prime application which increases efficiency and productivity in the fields of architecture, engineering and construction. There are five dimensions of BIM construction (3D, 4D, 5D, 6D and 7D), each of which has functions and features that can be used as needed. The five dimensions of construction facilitate the work of a construction project to be more effective and efficient, especially in a technology-based era nowadays. On that basis, it is necessary to examine the factors affecting the demolition work of high-rise buildings with Line of Balance (LOB) scheduling and Building Information Modelling (BIM) implementation. In addition to avoid cost overruns, the relatively long demolition work can cause environmental pollution and other problems.

LITERATURE REVIEW

Method of Demolition

There are two types of demolition methods, using explosives and non-explosives. The method of demolition may vary, depending on the area where the demolition is carried out, the availability of tools, the purpose of the demolition and the final disposal site for debris [1]. According to [2], the factors that are taken into consideration in planning the demolition project, including; main types of construction, safety concerns, costs, access in the field, protection of surrounding structures, unforeseen conditions, scheduling, work sequences, disposal, recycling, reuse of materials, various regulations and standards that apply to the demolition industry, such as; safety, project area environmental requirements, environmental requirements for hazardous materials and other specific regulations. Based on some of the important factors above, it is necessary to conduct a study before determining the appropriate demolition method to be used. Refer to the summary of the characteristics of each demolition method, in the Code of Practice for Demolition of Buildings [3], the proper demolition method to be applied in the city of Jakarta and other big cities in Indonesia is top-down by machine.

Top-Down by Machine

This demolition method is usually used in low-rise or high-rise building types, where land or free space is the main obstacle. The top-down demolition method is to dismantle in the vertical direction in the reverse order of the multi-storey building construction. So, the difference in the top-down by machine dismantling method lies in the use of heavy equipment (machine), to help the unloading process to be more effective and efficient. Compared to other dismantling methods, the top-down by machine method is the safest [4]. The sequence of dismantling top-down by machine method is generally adjusted to the actual conditions in the field, restrictions, the original building layout and its construction.

Demolition Management

As an independent project, demolition construction involves planning, design and implementation, as well as its unique issues, such as making decisions about alternative building demolition, handling and disposal of demolition waste. As demolition works have serious impacts on the surrounding environment, demolition project planning is generally based on demolition permits approved by government departments or authorities. The success of debt demolition projects on demolition technology and project management principles [5].

Scheduling

According to [6], the success key of implementing a project on time is complete and precise project planning and scheduling. Delays can be considered as a result of not fulfilling the planned schedule, because the actual conditions are not the same / in accordance with the conditions when the schedule was made. In a construction project, there are several scheduling methods can be used. However, for the case of repetitive activities such as building demolition, generally using the Linear Balance Methods or well-known as Line of Balance (LOB) [7].

Line of Balance (LOB)

This method is felt to be the most effective and efficient for projects that have repetitive activities, both horizontal and vertical. According to [8], the Line of Balance (LOB) scheduling method can increase efficiency by 20% so that it is more efficient in terms of cost and time. Applying the LOB method to a project scheduling, must be focus on the work items because there are some items could not be scheduled using this LOB method, only the repetitive work items can be scheduled [9]. Generally, scheduling using LOB consists of several stages, including [10]; (a) prepare a logic diagram showing the production sequence of one repeating job cycle, (b) estimates the number of work squads for each activity, (c) prepare a LOB schedule, (d) determines the buffer time (if desired), (e) draw the LOB chart.

Building Information Modelling (BIM)

By using the BIM application, there are many benefits which can be obtained. The concept carried by BIM means creating visual - virtual modelling, then analysed to reduce uncertainty, increase safety, solve problems, and potential impacts. It helps all activities in the scope of construction to be more transparent and coordination to be faster and easier [11]. Many developed and developing countries have used it. Meanwhile in Indonesia, based on Indonesia's digital construction roadmap, the development of BIM in 2017 has only entered the adoption stage, while the BIM integration phase will be fully implemented in 2024. In this technology-based era, BIM will arise as a prime application. It helps a lot, especially in the scope of design, planning and supervision, since it can increase efficiency and productivity. No exception in building demolition work.

MATERIALS & METHODS

Flowchart

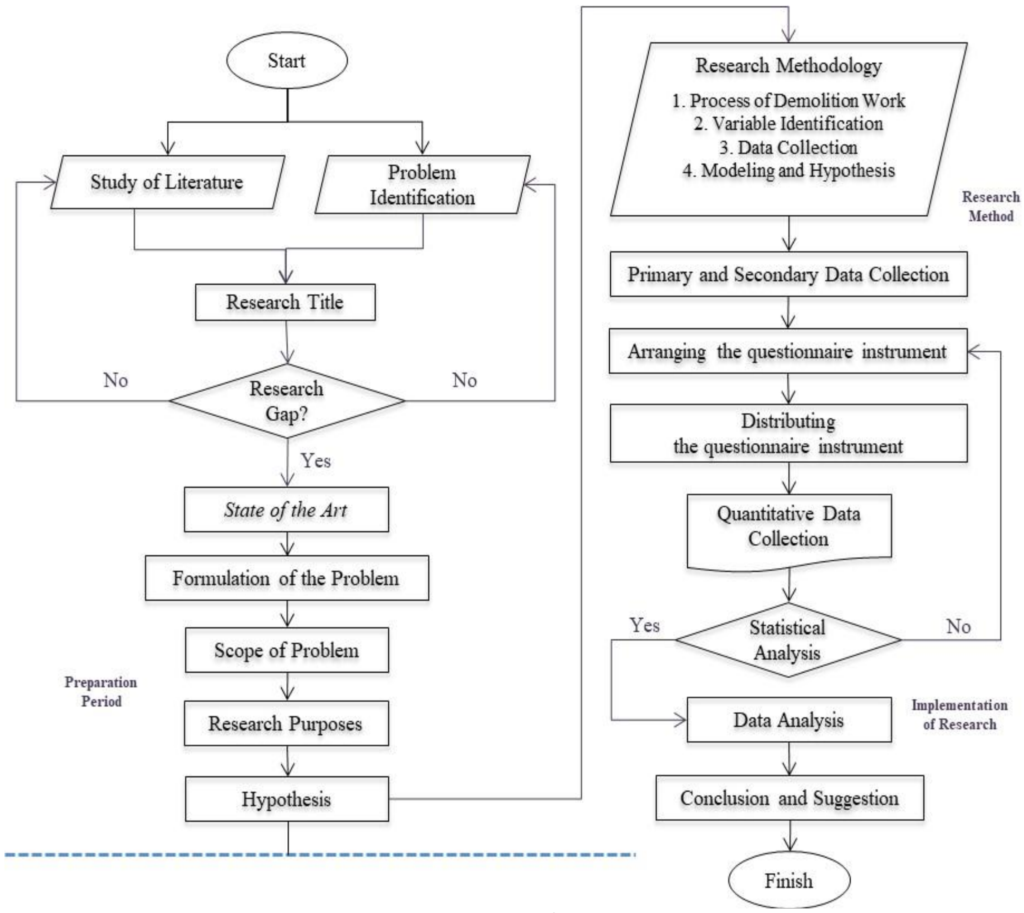

Figure 1. Research flow diagram

This study used a quantitative approach, with a descriptive research design type. In order to answer the problem formulation, the research flow is systematically designed in the form of a flow chart. Broadly speaking, the flow of these stages aims to facilitate the conduct of research. The flow chart in this study is following below:

From the flow chart above, it can be seen that this study used a questionnaire instrument. It conducted by giving a set of questions to the respondent to be answered in order to find the key success factors in implementing Line of balance (LOB) scheduling and the Building Information Modelling (BIM) application in top-down by machine demolition work.

Identification of Variables

This study has 3 independent variables and 1 dependent variable for processing and analysing the results of factors affecting the implementation of LOB and BIM in demolition work. These variables are:

- Dependent Variable:

[X1] Line of Balance (LOB) scheduling
[X2] Building Information Modelling (BIM) software
[X3] Demolition - Top-Down by Machine

- Independent Variable: [Y1] Time

Independent and dependent variables in the regression equation:

$$Y = a + b.X1 + c.X2 + d.X3 \text{…………}(1)$$

Identification of these variables is obtained by looking for the key success factors from various references, including books and journals. There are 31 sub-factors found which classified into 3 independent variables and 1 dependent variable. Here is the list of key success factors in this study:

Table 1. Key Success Factors List

Variable	Main Factor	Sub-Factor	
X1	**Line of Balance (LOB) Scheduling**	X1-1	Effective for repetitive work
		X1-2	Visual appearance so easy to understand
		X1-3	Work sequence analysis
		X1-4	Analysis of sustainable resource
		X1-5	Analysis of buffer time – worker and equipment waiting time
		X1-6	Able to reduce project duration
		X1-7	Easier to modify, update and change the schedule
X2	**Building Information Modelling (BIM) Software**	X2-1	Design optimization
		X2-2	Visualization of the planning process (construction method)
		X2-3	Scheduling simulation and visualization
		X2-4	Identification of work activities
		X2-5	The work stages are clearer
		X2-6	Faster decision making
		X2-7	Integration of information between work packages
		X2-8	Effective coordination between one another
		X2-9	Risk reduction
		X2-10	Having ability to achieve performance targets effectively and efficiently
X3	**Demolition - Top-Down by Machine**	X3-1	Survey the physical condition of the building
		X3-2	Structure stability report with supporting calculations
		X3-3	Demolition work sequences
		X3-4	Analysis of heavy equipment requirements
		X3-5	Waste management
		X3-6	Analysis of material properties (type, volume, area, weight and properties; recyclable or reusable)
		X3-7	Competent Human Resources (HR)
		X3-8	Occupational Health, Safety and Work Welfare
		X3-9	Preventive action plan and emergency condition
		X3-10	Environmental conditions
Y	**Time**	Y1-1	Optimization of project duration
		Y1-2	Work complexity
		Y1-3	Delay in previous work
		Y1-4	Incorrect determination of the duration of work

Determination of the Number of Respondents

The survey was conducted by giving a series of questions to respondents who were involved in the demolition project. The number of people targeted to fill in the question set is obtained from the following equation:

$$\mathbf{n} = \frac{m}{1+\left(\frac{m-1}{N}\right)} \quad \text{.............................}(2)$$

$$\mathbf{m} = \frac{Z^2\ x\ P\ x\ (1-P)}{\varepsilon^2} \text{.......................}(3)$$

If :
N = 31 questions
Z = 1.96 (assuming a confidence level of 0.95)
P = 0.5
E = 0.05

From the above equation, the number of respondents is 29 respondents. The target respondents are planning consultants, project owners, project managers, site engineers, QS managers, and supervisors.

RESULT

Relative Importance Index (RII) Method

Generally, the Relative Importance Index (RII) is used to analyse various factors affecting worker productivity in construction related to project implementation. The score of each factor is obtained by the sum of the respondent's answers. RII is calculated by the following equation:

$$RII = \frac{\sum_{i=1}^{i=A} n_i \times i}{A \times N} \text{.........................}(4)$$

The results of the questionnaire are then sorted from largest to smallest, to determine the most influencing factors. Then it compiled into a recapitulation which is presented into sub-factor ranks; 10 most influential sub-factors, 10 least influential sub-factors and ranking the most influential main-factor. The results of data analysis can be seen in the following table:

Table 2. Results of Relative Importance Index (RII) Analysis

Variable	Main Factor	Sub Factor	Sub - Factor		Main- Factor	
			RII	Rank	RII	Rank
X1	Line of Balance (LOB) Scheduling	X1	0,593	15	0,649	I
		X2	0,614	12		
		X3	0,579	16		
		X4	0,628	11		
		X5	0,800	1		
		X6	0,772	2		
		X7	0,559	18		
X2	Building Information Modelling (BIM) Software	X8	0,752	3	0,578	III
		X9	0,607	13		
		X10	0,600	14		
		X11	0,579	16		
		X12	0,566	17		
		X13	0,469	24		
		X14	0,559	18		
		X15	0,648	8		
		X16	0,503	20		
		X17	0,497	21		
X3	Demolition - Top-Down by Machine	X18	0,552	19	0,586	II
		X19	0,559	18		
		X20	0,690	5		
		X21	0,669	7		
		X22	0,676	6		
		X23	0,600	14		
		X24	0,641	9		
		X25	0,497	21		
		X26	0,490	22		
		X27	0,483	23		
Y	Time	Y1	0,697	4	0,571	IV
		Y2	0,634	10		
		Y3	0,469	24		
		Y4	0,483	23		

Table 2. List of sub-factor rank

Rank	Sub - Factor	Main Factor
1	Analysis of buffer time - worker and equipment waiting time	LOB Scheduling
2	Able to reduce project duration	LOB Scheduling
3	Design optimization	BIM Software
4	Optimization of project duration	Time
5	Demolition work sequences	Demolition - Top-Down by Machine
6	Waste management	Demolition - Top-Down by Machine
7	Analysis of heavy equipment requirements	Demolition - Top-Down by Machine
8	Effective coordination between one another	BIM Software
9	Competent Human Resources (HR)	Demolition - Top-Down by Machine
10	Work complexity	Time
11	Analysis of sustainable resource	LOB Scheduling
12	Visualization of the planning process (construction method)	BIM Software
13	Visual appearance so easy to understand	LOB Scheduling
14	Scheduling simulation and visualization	BIM Software
14	Analysis of material properties (type, volume, area, weight and properties; recyclable or reusable)	Demolition - Top-Down by Machine
15	Effective for repetitive work	LOB Scheduling
16	Identification of work activities	BIM Software
16	Work sequence analysis	LOB Scheduling
17	The work stages are clearer	BIM Software
18	Integration of information between work packages	BIM Software
18	Easier to modify, update and change the schedule	LOB Scheduling
18	Structure stability report with supporting calculations	Demolition - Top-Down by Machine
19	Survey the physical condition of the building	Demolition - Top-Down by Machine
20	Risk reduction	BIM Software
21	Having ability to achieve performance targets effectively and efficiently	BIM Software
21	Occupational Health, Safety and Work Welfare	Demolition - Top-Down by Machine
22	Preventive action plan and emergency condition	Demolition - Top-Down by Machine
23	Incorrect determination of the duration of work	Time
23	Environmental conditions	Demolition - Top-Down by Machine
24	Faster decision making	BIM Software
24	Delay in previous work.	Time

DISCUSSION

The first and second ranks show the factors that are influenced by Line of Balance (LOB) scheduling. This is aligned with the most effective method of scheduling for repetitive activities, including demolition work in high rise building. According to [12], LOB is a good visual because we can see a construction project can be accomplished in a short time between tasks, especially it is primarily used on project that have repeated elements.

Furthermore, the third factor is influenced by the application of Building Information Modelling (BIM). As commonly used, BIM applications exist as an effective process that increases efficiency and productivity in the fields of architecture, engineering and construction. Because it has characteristics that support design optimization, namely the simulation stage. As stated by [13], in terms of effectiveness and productivity, BIM gives advantages for scheduling, design, implementation, and facility management, as well as BIM helps many stakeholders involved the project.

The next factor is influenced by time, where it is one of the main goals. So, the project able to accomplish on time and there is no cost overruns. Meanwhile, the fifth, sixth and seventh factors are influenced by the demolition top-down by machine. The method that is considered is the most effective [3]. This is very suitable to be applied in big cities such as Jakarta.

Most of the articles included in the review have been published, Line of Balance (LOB) scheduling are particularly suitable for projects that have repetitive activities. However, the exploration tends to be limited to a construction work, not a building demolition. As well as the Building Information Modelling (BIM) which tends to be used for development projects. So, both of combination can be used as a reference in future demolition planning, which of course is expected to be much more detailed and to achieve all project goals.

The scope of this research is still very limited only to dismantle of building structures. Has not discussed further, such as facades removal, sanitation and other elements. In addition, it also includes building debris and efficient logistic time requirement. Building demolition becomes a very interesting thing. The waste materials can be reused to maintain the balance of nature, which does not only end up being useless stack of material waste. For example, those materials can be recycled into concrete or paving blocks and other types. Residual reinforcing iron and other elements can also be reused. With proper planning, good steps, some elements of the building can be saved from being converted to reduce operating costs.

CONCLUSION AND RECOMMENDATION

Equal to build a building, demolition work also requires good planning. This study has successfully identified factors affecting the implementation of Line of Balance (LOB) scheduling and Building Information Modelling (BIM) in top-down by machine demolition work. Based on the Relative Importance Index (RII) method, the top 10 rankings of factors that affect the implementation of Line of Balance (LOB) scheduling and Building Information Modelling (BIM) in top-down by machine demolition work are obtained, as follows:

1. Analysis of buffer time - worker and equipment waiting time.
2. Able to reduce project duration
3. Design optimization
4. Optimization of project duration
5. Demolition work sequences
6. Waste management
7. Analysis of heavy equipment requirements
8. Effective coordination between one another
9. Competent Human Resources (HR)
10. Work complexity

From these results, it also be seen that 10 ranks of less influential factors, as follows:

1. Structure stability report with supporting calculations
2. Survey the physical condition of the building
3. Risk reduction
4. Having ability to achieve performance targets effectively and efficiently
5. Occupational Health, Safety and Work Welfare
6. Preventive action plan and emergency condition
7. Incorrect determination of the duration of work
8. Environmental conditions
9. Faster decision making
10. Delay in previous work.

In order to ensure the factors affecting, it is necessary to conduct further pilot studies of the top-down by machine demolition project with the implementation of Line of Balance (LOB) scheduling, as well as Building Information Modelling (BIM) software. Therefore, the level of efficiency can be known.

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