ABSTRACT

Currently, the construction of high-rise buildings is increasingly being carried out, in line with economic growth in big cities, but vacant land for settlements, offices and residential buildings is very little or limited, as well as the high price of land in cities. The level of housing needs in Indonesia. In Indonesia until 2025 it is estimated that it will require housing around 1,513,865 residential units, so that the need for residential units in cities is very large, to cope with limited land and high prices of land in the city, now to meet the residential needs, buildings are made vertically (highrise), but with limited land and rampant construction of high-rise buildings have an effect on the need for parking lots, to overcome this, a basement was made, which could be used as a parking area in addition to other functions such as utility rooms and others. In the implementation of high-rise building construction projects, good scheduling and quality control play a very important role, in the timeliness, cost and quality / quality of project completion as a whole [2]. The success of a construction project is based on 3 things, namely cost, quality and time. To control cost, quality and time in this study using the Lean Six Sigma and Last Planner System methods. By using this method, it will control waste (waste) and control scheduling so that work delays do not occur. To get the factors that affect cost efficiency, quality and time, researchers use analysis with SPSS software (Statistical Package for the Social Sciences), with SPSS 10 key success factors that can streamline costs, quality and time are obtained as follows: 1. Reduction costs, 2. Improve communication among project participants, 3. Knowledge of the project, 4. Planning Process, 5. Predictable Work Plan, 6. Prepare a weekly plan, 7. BoQ, 8. Image, 9. Damaged Soil Removal Method, 10. Weather Conditions. These 10 factors are expected to make cost, quality and time efficiency in construction implementation.

Key Words: Lean Six Sigma, Last Planner System, Statistical analysis.

1. INTRODUCTION

Currently, the construction of high-rise buildings is increasingly being carried out, in line with economic growth in big cities, but vacant land for settlements, offices and residential buildings is very little or limited, as well as the high price of land in cities. Based on the 2010-2035 Indonesian Population Projection report (Central Statistics Agency (BPS), n.d.), the current population of Indonesia in 2020 will reach 271.1 million people can be seen in the figure 1.
To cope with limited land and high land prices in the city, to meet the residential needs a vertical building is made (highrise), the construction of a high-rise building has an effect on the need for parking space, to overcome this, a basement is made, which can be used as a parking space in addition to other functions, such as utility rooms and others, for the estimated residential needs from 2012 - 2025 it can be seen from the table 1.2

![Figure 1: The population of people in urban areas][3]

![Figure 1.2: Housing needs in several countries][4]

According to [5] The cost of building a basement ranges from Rp. 6.0 million to Rp. 8.0 million, including foundation work and external works, as shown in the figure 1.3:

![Figure 1.3: Construction cost per m2 of basement][1]
According to [6] Turner & Townsend, for the construction cost of a basement around Rp. 5.5 million to Rp. 7.0 M, as can be seen in the table below:

| Building Type            | Cost per m² |
|--------------------------|-------------|
| Domestic (including basic services) | 25,000,000 |
| Low-cost commercial (including basic service) | 18,500,000 |
| Office (including basic service) | 9,500,000  |
| CBD Offices - up to 20 floors (A-Grade) | 11,500,000 |
| CBD Offices - High-rise (prestige) | 15,000,000 |
| Primary and secondary | 8,500,000  |
| University | 11,500,000 |
| Day centre (including basic services) | 18,000,000 |
| Regional hospital (including city teaching hospital) | 18,500,000 |
| General hospital | 21,000,000 |
| Retail | 12,500,000 |
| 5 Star luxury | 21,000,000 |
| Resort style | 26,000,000 |
| Warehouse/factory units - basic | 5,500,000 |
| Large warehouse distribution centre | 31,000,000 |
| High-tech factory/laboratory | 15,000,000 |
| Individual detached house - prestige | 13,000,000 |
| Townhouses - medium standard | 8,000,000  |
| Apartments - low-rise medium standard | 9,000,000  |
| Apartments - high-rise | 9,000,000  |
| Aged care/affordable units | 6,000,000  |

**Figure 1.4 Construction cost per m² of basement**

So if we see from the three sources above (Figures 1.3 to 1.4) that the costs for building a basement are quite expensive, so it is necessary to calculate and supervise very tightly, from planning to implementation, so that it can reduce both errors, a matter of time and waste (waste).

**2. LITERATURE REVIEW**

**2.1 Lean Six Sigma**

Lean Six Sigma is a combination of lean and six sigma which can be defined as a business philosophy, systemic and systematic approach to identify and eliminate waste or activities that are not value added through radical continuous improvement to reach the six sigma level. (six sigma). The Six Sigma methodology uses statistical tools to identify several vital factors. The most determining factors to improve process quality and generate profit consist of 5 stages called DMAIC (define, measure, analyze, improve, control) [7], as shown in figure 1.5:

**Figure 1.5 Six Sigma Cycle [8]**
2.2 Last Planner System (LPS)

Special emphasis is placed on the relationship between production scheduling and control, and also on phase planning techniques to determine when work can escape constraints or obstacles which are the focus of Last Planner (Lean construction Indonesia 2020). Lean Construction is about building projects while providing value, minimizing waste and achieving excellence for the benefit of all stakeholders [9]. The benefits of Lean Construction techniques have been demonstrated by achieving the improvement of multiple projects and each stage of the project. Lean Construction takes more time in the design and planning stages, but this attention eliminates or minimizes conflicts that can dramatically change costs and schedules [10].

2.2.1 Work Flow Control LPS

In this system, there are performance indicators that are used to measure the extent to which work flow can be achieved properly, as for the Last Planner System work flow control, namely:

- **Master Plan** *(Master Planning)*
  To get a general plan and identify all work for the whole project show the main activities, duration, and sequence.

- **Pull Planning**
  The function of the planning phase is to produce a detailed schedule that includes each phase of the project as a foundation in determining further planning, structural framework, and finishing. In making this planning phase, it is more profitable if it is done with a team [12].

- **Lookahead Planning (Make Work Ready Planning)**
  Lookahead planning describes the first step of LPS planning with a duration typically ranging from two to six weeks. At this stage, activities are broken down to the process / operation level, constraints are identified, job responsibilities are assigned to each person (implementation), and work assignments are ready to be carried out [13].

- **Weekly Work Planning (WWP)**
  WWP directly illustrates the relationship between job tasks to drive the production process. At the end of each period, monitoring and evaluation is carried out to analyze whether the plans made were effective, and what obstacles were faced [14].

- **Percent Plan Complete (PPC)**
  PPC is the number of assignments that have been completed divided by the number of all assignments planned, and written as a percentage (H. G. Ballard, 2000). The equation is as follows:

  \[
  
  \text{PPC (\%)} = \frac{\text{The number of work plans performed successfully}}{\text{Total Work Plan}} \times 100
  
  \]

  \[
  \text{………………………………………(1)}
  
  \]
2.3 Basement
Basement is a vertical downward development that creates an underground space (Basement) which is part of the building. Basement implementation method according to [15] There are 3 methods, namely the open cut method, the bottom up method and the top down method, as follows:

![Basement Implementation Method]

Figure 1.7 Basement Implementation Method

2.4 Bore Pile
Bored pile foundation is a pile foundation whose installation is done by drilling the ground first [16]. Bored pile foundation is one type of foundation which is part of the construction made of concrete and steel reinforcement [17]. For the drilling method, it can be used with the dry boring method, or you can also use the wash boring technique.

2.5 Secant Pile
Secant Pile is a Soil Retaining Wall which is included in the In-situ type which is used in narrow areas because this method does not require water. According to [18] secant pile in its implementation requires more concrete material and reinforcement and requires a longer time than concrete sheet pile. Secant pile can also be applied to soils with difficult conditions or high groundwater levels.

2.6 Excavation
Excavation or excavation is one of the stages in earthworks [19].

3. RESEARCH METHODOLOGY
This research process contains a research flow from the beginning to finding a hypothesis to answer the problem formulation by conducting scientific research, where in the process there are stages / sequences that are adjusted to the research framework that has been compiled in the form of a flow chart. The flow chart is prepared based on the formulation and research objectives to be achieved by referring to the project feasibility study [20].
The data that has been collected is continued by processing and analyzing the data to get the initial data results. From the findings of these preliminary data, discussion analysis processing is then carried out to be able to draw conclusions about the process of cost, quality and time efficiency.

3.1 Variable Identification

In this case the researcher takes 2 (two) main variables to get cost efficiency and time accuracy as independent variables, and 3 (three) variables as dependent. The variables are:

Independent Variable : X1 = Lean Six Sigma
X2 = Last Planner System
X3 = Basement

Dependent Variable: Y1 = Cost
Y2 = Time

The identification of sub variables related to cost performance, quality and project time consists of 5 variables, namely Lean Six Sigma, Last Planner System, Time and Cost Basement. The number of respondents used in this study was 51 respondents. The following factors affect the increase in cost, quality and time performance.

| No | Variable                  | Main Factor | Sub Factor                                      | Reference                     |
|----|----------------------------|-------------|-------------------------------------------------|-------------------------------|
| 1  | Lean Six Sigma (X1)        | Define      | X1-1 Cost reduction                            | Jeyaraman (2010), Emerald     |
|    |                            |             | X1-2 Elimination or reduction of waste          | Jeyaraman (2010), Emerald     |
|    |                            |             | X1-3 Product quality                           | Jeyaraman (2010), Emerald     |
|    |                            |             | X1-4 Productivity                              | Jeyaraman (2010), Emerald     |
|    |                            |             | X1-5 Flexibility                               | Jeyaraman (2010), Emerald     |
|    |                            | Measure     | X1-6 Material use and storage systems           | Weisheng Lua, Hongping Yuanb,(2010) |
|    |                            |             | X1-7 Fewer design changes                      | Weisheng Lua, Hongping Yuanb,(2010) |
|    |                            |             | X1-8 Improve communication among project participants | Weisheng Lua, Hongping Yuanb,(2010) |
|    |                            |             | X1-9 Waste Management Regulations               | Weisheng Lua, Hongping Yuanb,(2010) |
|    |                            | Analyze     | X1-10 Knowledge of the project                 | (Schön et al., 2010)          |
|    |                            |             | X1-11 The whole process of Aligning the agenda involved | (Schön et al., 2010)          |
| No | Variable | Main Factor | Sub Factor | Reference |
|----|----------|-------------|------------|-----------|
| 1  | Lean Six Sigma (X1) | Analyze | X1-12 | Project leaders lack understanding of the process | (Schön et al., 2010) |
|    |          |            | X1-13 | Availability of experts | (Schön et al., 2010) |
|    |          |            | X1-14 | Availability of “people who are suitable in their fields” | (Schön et al., 2010) |
|    |          | Improve   | X1-15 | Supported operating system | J.P. Verma (2012) |
|    |          |            | X1-16 | Application updates | J.P. Verma (2012) |
|    |          |            | X1-17 | Supported PC devices | J.P. Verma (2012) |
|    |          | Control   | X1-18 | Level of Defects in the Work Process | Nascimento (2019), Emerald |
|    |          |            | X1-19 | Evaluating Quality | Nascimento (2019), Emerald |
|    |          |            | X1-20 | Reduction of Variability | Nascimento (2019), Emerald |
| 2  | Last Planner System (X2) | Planning  | X2-1 | predictable work plan | Aziz (2013), Alexandria Engineering Journal |
|    |          |            | X2-2 | reduce project delivery time | Aziz (2013), Alexandria Engineering Journal |
|    |          |            | X2-3 | increased productivity | Aziz (2013), Alexandria Engineering Journal |
|    |          | Supporting Implementation | X2-4 | Production process | (Tayeh, Al Hallaq, Al Faqawi, Alaloul, & Kim, 2018) |
|    |          |            | X2-5 | Planning process | (Tayeh et al., 2018) |
|    |          |            | X2-6 | Eliminates Waste In Your Workflow | (Tayeh et al., 2018) |
|    |          |            | X2-7 | Level of Defects in the Work Process | (Tayeh et al., 2018) |
|    |          | Weekly Planning | X2-8 | prepare a weekly plan | AlSehaimi (2014) Emerald |
|    |          |            | X2-9 | Identify reasons for incomplete | AlSehaimi (2014) Emerald |
|    |          |            | X2-10 | Calculating PPC | AlSehaimi (2014) Emerald |
|    |          |            | X2-11 | Perform a constraint analysis | AlSehaimi (2014) Emerald |
| 3  | Basement (X3) | Preparatory work | X3-1 | technical specifications | Husin et al (2019) |
|    |          |            | X3-2 | BoQ | Husin et al (2019) |
|    |          |            | X3-3 | Time | Husin et al (2019) |
| 4  | Cost (Y1) | Cost | Y1-1 | Bad Design and Delays in Design | Hamed Samarghandi et al.(2016) |
|    |          |            | Y1-2 | Unrealistic contract duration | Hamed Samarghandi et al.(2016) |
|    |          |            | Y1-3 | Lack of experience | Hamed Samarghandi et al.(2016) |
|    |          |            | Y1-4 | Late delivery of materials and equipment | Hamed Samarghandi et al.(2016) |
|    |          |            | Y1-5 | The relationship between management and labor | Hamed Samarghandi et al.(2016) |
Table 1.1 Key Success Factors

| No | Variable | Main Factor | Sub Factor | Reference |
|----|----------|-------------|------------|-----------|
| 4  | Cost (Y1)| Cost        | Y1-6 Delays Preparation and approval of drawings | Hamed Samarghandi et al. (2016) |
|    |          |             | Y1-7 Inadequate planning and scheduling | Hamed Samarghandi et al. (2016) |
|    |          |             | Y1-8 Poor site management and supervision | Hamed Samarghandi et al. (2016) |
|    |          |             | Y1-9 Error during construction | Hamed Samarghandi et al. (2016) |
|    |          |             | Y1-10 Changes to specifications and material types | Hamed Samarghandi et al. (2016) |
| 5  | Time (Y2)| Time        | Y2-1 Unforeseen weather | Seyed Mohammad Moosavi . At all | (2016) |
|    |          |             | Y2-2 Inaccurate predictions of artisan production levels | Seyed Mohammad Moosavi . At all | (2016) |
|    |          |             | Y2-3 Lack of material | Seyed Mohammad Moosavi . At all | (2016) |
|    |          |             | Y2-4 Lack of equipment | Seyed Mohammad Moosavi . At all | (2016) |
|    |          |             | Y2-5 Lack of skilled workforce | Seyed Mohammad Moosavi . At all | (2016) |
|    |          |             | Y2-6 Project location restrictions | Seyed Mohammad Moosavi . At all | (2016) |
|    |          |             | Y2-7 Poor labor productivity | Seyed Mohammad Moosavi . At all | (2016) |
|    |          |             | Y2-8 Design changes | Abd El-Razek, Bassioni and Mobarak (2008) |

3.2 Determination of Number of Respondents

The minimum number of respondents to answer the questionnaire is needed as a limitation in collecting the required results. According to [21] Respondents' needs can be obtained using the following equation:

\[
m = \frac{Z^2 \times P \times (1-P)}{\varepsilon^2}
\]

Where: \( N = 58 \), \( \varepsilon = 0.05 \), \( P = 0.5 \)

Based on value \( p \)-value is obtained by the Z value based on the normal distribution Z table, \( Z = 1.96 \). Then the minimum respondent needs are as follows:

\[
m = \frac{Z^2 \times P \times (1-P)}{\varepsilon^2} = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = \frac{0.96}{0.0025} = 384.16
\]

\[
n = \frac{m}{1 + \frac{m - 1}{N}} = \frac{384.16}{1 + \frac{384.16 - 1}{58}} = \frac{384.16}{7.61} = 50.5061
\]

Therefore, the minimum requirement for respondents is 51 respondents.

3.3 Data Processing Stage

In testing the validity of a measure that can show the validity or validity of the instrument. So in testing the validity it refers to an instrument in carrying out its function. Variables obtained from published journals, articles and e-books. The process of testing the validity and reliability is carried out using the following tools in the SPSS program, which is a data processing flowchart:
3.4 Validity Test and Reliability Test

From each variable will be tested using SPSS tools, namely the value of the corrected item total correlation (calculated validity) if the value is more than 0.2542 then it can be stated as valid and the value of Cronbach's Alpha (Calculated Reliability). If the value is more than 0.600 then can be stated as realistic, here are the results of data grouping that are both realistic and valid. [23]

Table 1.2 Validity Test Results

| Variable              | Alpha Cronbach | Comparative Value | Remark |
|-----------------------|----------------|-------------------|--------|
| Lean Six Sigma        | 0.401          | 0.2542            | Valid  |
| Last Planner System   | 0.627          | 0.2542            | Valid  |
| Basement              | 0.549          | 0.2542            | Valid  |
| Cost                  | 0.526          | 0.2542            | Valid  |
| Time                  | 0.577          | 0.2542            | Valid  |

Table 1.3 Reliability Test Result

| Variabel              | Alpha Cronbach | Comparative Value | Keterangan |
|-----------------------|----------------|-------------------|------------|
| Lean Six Sigma        | 0.722          | 0.600             | Reliabel   |
| Last Planner System   | 0.841          | 0.600             | Reliabel   |
| Basement              | 0.719          | 0.600             | Reliabel   |
| Cost                  | 0.707          | 0.600             | Reliabel   |
| Time                  | 0.722          | 0.600             | Reliabel   |
The results of the average analysis are then compiled into a recapitulation which is presented in the form of sub-factor rankings. The results of the recapitulation of statistical analysis using the average method, more details can be seen in the discussion below.

| Rank | Sub Factor                                           | Main Factor          |
|------|------------------------------------------------------|----------------------|
| 1    | Cost reduction                                       | Define               |
| 2    | Improve communication among project participants     | Measure              |
| 3    | Knowledge of the project                            | Analyze              |
| 4    | Planning process                                     | Supporting implementation |
| 5    | predictable work plan                                | Planning             |
| 6    | prepare a weekly plan                                | Weekly Planning + make ready |
| 7    | BoQ                                                  | Tender document      |
| 8    | Bad Design and Delays in Design                      | Cost                 |
| 9    | Picture                                              | Preparatory work     |
| 10   | Error during construction                            | Cost                 |
| 11   | The soil removal method is damaged                   | Preparatory work     |
| 12   | Lack of skilled workforce                           | Time                 |
| 13   | Weather conditions                                  | Preparatory work     |
| 14   | Unforeseen weather                                  | Time                 |
| 15   | Flexibility                                          | Define               |
| 16   | Project leaders lack understanding of the process    | Analyze              |
| 17   | Fewer design changes                                 | Measure              |
| 18   | Availability of experts                              | Analyze              |
| 19   | reduce project delivery time                         | Planning             |
| 20   | Poor labor productivity                             | Time                 |
| 21   | Identify reasons for incomplete                      | Weekly Planning + make ready |
| 22   | Soil type (e.g., sand, loam, rigid loam)             | Preparatory work     |
| 23   | Inadequate planning and scheduling                   | Cost                 |
| 24   | Lack of material                                     | Time                 |
| 25   | Availability of "people who are suitable in their fields" | Analyze              |
| 26   | Design changes                                       | Time                 |
| 27   | The whole process of Aligning the agenda involved    | Analyze              |
| 28   | Supported PC devices                                 | Process              |
| 29   | Lack of equipment                                    | Time                 |
| 30   | Unrealistic contract duration and terms imposed      | Cost                 |
| 31   | The relationship between management and labor        | Cost                 |
| 32   | Project location restrictions                        | Time                 |
| 33   | Elimination or reduction of waste                    | Define               |
| 34   | Evaluating Quality                                   | Improve              |
| 35   | Production process                                   | Supporting implementation |
| 36   | Productivity                                         | Define               |
| 37   | technical specifications                             | Tender document      |
| 38   | Level of Defects in the Work Process                 | Improve              |
| 39   | increased productivity                               | Planning             |
| 40   | Perform a constraint analysis                        | Weekly planning + make ready |
| 41   | Changes to specifications and material types         | Cost                 |
| 42   | Application updates                                  | Process              |
| 43   | Material use and storage systems                     | Measure              |
| 44   | Time                                                 | Tender document      |
| 45   | Lack of experience                                  | Cost                 |
| 46   | Drill type, size and construction method             | Preparatory work     |
| 47   | Late delivery of materials and equipment             | Cost                 |
| 48   | Eliminates Waste In Your Workflow                    | Supporting implementation |
| 49   | Calculating PPC                                      | Weekly planning + make ready |
| 50   | Delays Preparation and approval of drawings          | Cost                 |
| 51   | Reduction of Variability                             | Improve              |
| 52   | Poor site management and supervision                 | Cost                 |
| 53   | Hole depth and size                                  | Preparatory work     |
| 54   | Waste Management Regulations                         | Measure              |
| 55   | Product quality                                      | Define               |
4. CONCLUSION

The factors that greatly influence cost performance, quality, time are obtained from the processing of SPSS which has the highest index, namely:

1. Cost reduction
2. Improve communication among project participants
3. Knowledge of the project
4. The planning process
5. Predictable work plan
6. Prepare a weekly plan
7. BoQ
8. Bad design and delay in design
9. Image
10. Errors during construction

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