The Analysis of Stakeholder Influence and Role in Implementing Sustainable Construction by Observing the Principles of Lean Construction on Infrastructure Projects in Indonesia

Alvin Baskoro Adhi and Fadhilah Muslim*

Abstract—The construction industry is one of the industries that contributes the highest material consumption and emissions in the world. Lean construction is one of the principles in implementing sustainable construction as outlined in the PUPR Ministerial Decree No. 9 of 2021 concerning Guidelines for the Implementation of Sustainable Construction. This study aims to analyze the level of influence of stakeholders in lean construction, analyze the role of stakeholders in lean construction, and analyze the relationship between the level of influence of stakeholders on the role they have. Data analysis method using Factor of Stakeholder Influence Level (FoSIL) and correlation analysis. The findings show that the Government is the stakeholder with the highest level of influence. In addition, the roles of stakeholders are obtained, namely provider, context enabler, concept refiner, broker/mediator, initiator, stimulator, and regulator. From the correlation analysis, it is found that the greater the level of the role, the greater the level of influence and the stakeholder bargaining power. To increase the bargaining power, stakeholders can apply sub-roles that are owned by stakeholders with a higher level of influence.

Index Terms—Stakeholder role, stakeholder influence level, lean construction, sustainable construction

I. INTRODUCTION

Sustainable construction is the practice of constructing infrastructure and buildings design to meet the current needs with consideration for future needs. The implementation level of sustainable construction has a significant difference in developed countries and developing countries. Most of the developed countries have many years of experience in developing sustainable construction, while many developing countries are just starting to consider implementing sustainable construction through many construction requirements [1]. As a developing country, the increase in population is one of the biggest problems faced by Indonesia. According to the National Statistic Agency (BPS) in Indonesia, in the interval of 2010 to 2020 the average population increase reached 1.25% per year. It led to an increase in the number of daily basis necessities and fundamental primary needs. The imbalance of the supply and demand will result in an economic imbalance. Based on the National Statistic Agency (BPS) in Indonesia, in 2020 Indonesia experienced an aggregate economic contraction of −2.07% from 2019.

Infrastructures and buildings construction contribute about 5–10% global GDP and 10% global job acceptance [3]. Infrastructure developments and improvements are expected to fulfill the needs of logistics for goods and services as well as increasing the economic activities. It will affect and increase the economic circulation [2]. This shows the development of infrastructures and buildings will increase the Indonesia’s GDP. Studies also show that globally, infrastructure development and construction contributes about 5-10% global GDP and 10% global job acceptance [3].

However, the increasing infrastructure development is often accompanied by many negative impacts on the environmental factor. The construction industry is globally contributing around 40% of the global energy consumption, 40% of the global material consumption, 55% of the global timber consumption, and 12.2% of the global water consumption [4]. Furthermore, globally 2,01 billion tons of construction solid waste is generated, of which 33% is not properly processed. Based on that data, the construction solid waste is predicted to increase by 70% to 3.4 billion tons by 2050 [5]. Moreover, the increasing of infrastructure development has a social impact on the surrounding community. It can be happened because in developing countries there are differences in views and knowledge between the low education and the high education people [6].

Sustainable construction is a principle of fulfilling the needs of building and infrastructure construction and development with consideration for the future needs. Sustainable construction prioritizes efficiency and reduction which is one of the financial benefits offered from adapting sustainable construction. The adaptation of sustainable construction has enormous potential in supporting sustainability in construction industry through balancing in the use of energy in construction and operation stage of the infrastructures and buildings.

However, the increase in investment cost caused by the implementation of lean construction is the biggest financial problem faced by infrastructure construction project stakeholders. The level of uncertainty of the sustainability component applied to the projects is one of the factors that sustainable construction financing seems difficult [7]. By integrating sustainable construction into infrastructure and buildings there will be an increase in investment cost by 4.2%.

Lean construction is an alternative for overcome many problems including economic disadvantage in implementing sustainable construction. Lean construction is an adaptation of the concepts, principles, and tools of the Toyota

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Production System developed by Toyota. TPS focuses on reducing waste, reducing costs, increasing value to users, long-term development, and also continuous improvement [8].

To increase the implementation of lean construction, it requires high support and willingness from many stakeholders to act in the implementation of sustainable lean construction. Stakeholder management is one of the key successes to fully implementing sustainable construction. In case of implementing lean construction in developing country, several studies state that the government has the biggest involvement in promoting sustainable lean construction.

The Indonesians government’s support for lean construction is stated in the regulation of the Minister of Public Works and Public Housing (PUPR) of Republic of Indonesia number 9 of 2021 containing about the guidelines for the implementation of sustainable construction. One form of the sustainable construction implementation that regulated and driven by this regulation is in article 6 point 3, namely by applying the principle of lean construction.

To increase the implementation of sustainable lean construction in Indonesia, its necessary to adopt the Ministerial Regulation PUPR No. 9 of 2021 through many roles that carried out by each infrastructure construction stakeholders. Each role will determine the direction of the construction industry in Indonesia to adopt a sustainability and lean construction.

Based on this background, this paper will analyse about the impact, influence, and the roles that stakeholder have in infrastructure construction projects using sustainable and lean construction approach based on Ministerial Regulation PUPR no. 9 of 2021 that contain the guidelines for the implementation of sustainable construction in Indonesia. This research aims to increase the understanding of roles that each stakeholder carries to adapt sustainable lean construction in current and future infrastructure construction projects.

II. LITERATURE REVIEW

A. Sustainable Construction

Sustainable development is an alternative approach in the development of many industries that has the principle of meeting the current needs and considering about the future needs. The concept of sustainable construction is an implementation of the concept of buildings and infrastructures that is environmentally friendly (green construction) as a concern for the environmental impact caused by construction activities.

Sustainable construction has three main pillars which correspond to each other that have to be considered and implemented in infrastructure construction, namely social, economic, and environmental aspect. The balance of these three aspect is achieved by developing the interaction of 2 from the sustainability aspect, namely equitable, viable, and bearable [9].

The form of implementing sustainable construction does not only lie in the infrastructure construction phase, but the stakeholders have to take into account the after effect. An example of a good framework for implementing sustainable construction is to add sustainability criteria to the planning, operational, demolition, and recycling phases of the building waste materials management [10].

The social aspect of the sustainable construction is one of the three aspect of sustainability which is an indicator of achieving sustainable construction. Social aspect of sustainability is the involvement of employees, clients, supply chain actors, and community organs to meet the current and future needs [11].

The economic aspect is the most important aspect that determines the willingness of the infrastructure construction stakeholders to adopt the concept of sustainable construction. Economic sustainability is the fulfillment of the needs the principal and concept of efficiency in all aspect of the construction process, such as energy efficiency and material efficiency which has an impact on reducing construction cost and increasing productivity [12].

The environmental aspect of sustainability is the fulfillment of the current needs and protecting the ecological balance of the existing environmental system from damage caused by construction activities. Some aspect that can be reviewed in environmental sustainability are water management, sustainability management, energy efficiency, waste management, pollution, and user convenience [13, 14].

There are many drivers and barriers in sustainable construction adaptation. Efficiency and conservation of energy and resource are key drivers for stakeholders. Energy and resource efficiency can reduce the amount of energy and cost needed to achieve the infrastructure goal. This efficiency of budget use is a very good indicator for stakeholders to accept sustainable construction. Surely, this must be supported by sufficient regulation and standards from government.

However, any financial investment increase is a major barrier for stakeholders to adapt sustainability aspects on infrastructure. For many stakeholders, investment decision-making becomes complicated when the financial sustainability component is not yet clear [7].

B. Infrastructure Construction Projects

Infrastructure can be interpreted as a basic function that initiate changes in various economic variables, such as changes in company costs and home utilities [15]. Urban infrastructure function as a social link for humanity by providing the access of energy, water, telecommunications, transportation, and other needs.

The term infrastructure is often associated with physical or technical infrastructure such as the structure of a public utility network such as roads, railroads, airports, clean water infrastructure, and may others. There are three categories, that is Institutional Infrastructure, Personal Infrastructure, and Physical infrastructure. Physical Infrastructure has several classifications based on the type of the industry, such as transportation, water supply, disposal, irrigation, waste disposal, telecommunications, and energy [16].

Currently, infrastructure construction is one of the highest contributors to raw material and energy consumption among other industry. Sustainable construction is an alternative solution in infrastructure development. Sustainable infrastructure has a very close relationship with green
Stakeholder management is an important aspect of project management to ensure that projects meet their objectives and stakeholders are satisfied. Stakeholder management involves identifying, engaging, and managing stakeholder expectations and concerns to achieve project success. This section discusses the importance of stakeholder management in project success and presents a framework for managing stakeholder expectations.

### 3.1 Importance of Stakeholder Management

Stakeholder management is crucial for project success because stakeholders have varying interests, expectations, and perspectives. Managing stakeholder expectations can help mitigate conflicts, reduce project risks, and improve project outcomes. Effective stakeholder management can lead to increased stakeholder satisfaction, reduced project risks, and improved project outcomes.

### 3.2 Stakeholder Identification

Stakeholder identification is the process of identifying stakeholders who may be affected by or can affect the project. Stakeholders can be individuals, groups, or organizations with interests in the project. Stakeholder identification is often done using a stakeholder register, which is a list of stakeholders and their characteristics.

### 3.3 Stakeholder Engagement

Stakeholder engagement involves communicating with stakeholders, involving them in decisions, and managing their expectations. Stakeholder engagement can be done through various methods, such as meetings, surveys, and workshops. Effective stakeholder engagement can help ensure that stakeholders are satisfied with the project and that their expectations are met.

### 3.4 Stakeholder Management Framework

Stakeholder management involves several key processes, including:

1. **Stakeholder Identification:** Identifying stakeholders based on their influence and interest in the project.
2. **Stakeholder Engagement:** Engaging stakeholders in project decisions and communication.
3. **Stakeholder Engagement Planning:** Planning the approach for stakeholder engagement.
4. **Stakeholder Monitoring:** Monitoring stakeholder engagement and feedback.

### 3.5 Success Factors

Effective stakeholder management requires several success factors, including:

- **Clear Communication:** Communicating with stakeholders in a clear and concise manner.
- **Responsive Decision-Making:** Making decisions that address stakeholder concerns.
- **Balanced Consideration:** Considering the interests of all stakeholders equally.
- **Flexible Approaches:** Adapting stakeholder management strategies based on stakeholder responses.

By implementing effective stakeholder management, projects can achieve greater success and stakeholder satisfaction.
stakeholders involved in various life cycle of the infrastructure. Infrastructure development projects usually gave a large duration and investment value so that there is a complex stakeholder engagement structure is many infrastructures construction projects. Apart from the complexity, generally stakeholders can be divided into government organization, owners, designers, contractors, consultants, and suppliers.

E. Ministry of PUPR Regulation No. 9 of 2021
The regulation of the Minister of Public Housing and Public Housing Republic of Indonesia (PUPR) number 9 of 2021 is containing the guidelines for the implementation of sustainable construction. This regulation is one form of support that given by the government of the Republic of Indonesia about sustainability.

According to Ministerial Regulation PUPR No. 9 of 2021, sustainable construction is an alternative approach in buildings and infrastructures construction activities to fulfill the current and future economic, social, and environmental needs. Based on the sustainable construction implementation procedures from this regulation, the implementation needs to be carried out in an integrated and efficient system by considering the principles of lean construction and the use of building information modelling (BIM).

As one of the supporting principles to the implementation of sustainable construction, lean construction has several principles and tools that intersect with the indicators of sustainable criteria in the Ministerial Regulation PUPR No. 9 of 2021. The intersection between the lean principles and the sustainability criteria is developed into a sustainable lean construction performance indicator that will be carried in this paper. The sustainable lean construction indicator criteria include:

- Safety, health, environment, and security criteria,
- Sustainable structural design criteria,
- End-user fulfillment in production process criteria,
- Appropriate and efficient land use criteria,
- Energy efficiency and conservation criteria,
- Water efficiency and conservation criteria,
- Material efficiency and utilization, local material usage, and natural resource cycle criteria.

III. RESEARCH METHODOLOGY
Various techniques were used in this study in addition to the literature review to reach this research objectives. This research is carried out in qualitative and quantitative approach to reach the stakeholder influence level and the role owned by each stakeholder. Table I explained the research stages, objectives and methodologies carried.

In the first stage, a literature review and variable validation conducted to identify the major stakeholder and this research variables. Semi-Structured Interviews was conducted to 3 experts in sustainable construction.

In the second stage, a pilot study was conducted to 10 respondents each representing many different companies in the construction industries. Their input is used to improve the quality and finalize the questionnaire survey and interview questions.

A questionnaire survey was carried out in the third stage of this study. A factor of stakeholder influence levels (FoSIL) is used in the second stage to quantify the influence that possessed by various stakeholder in sustainable lean construction decision-making. The interview is intended to obtain the role possessed by each stakeholder.

The factor of stakeholder influence levels (FoSIL) calculated by involving two parameters, the vested interest-impact index (ViII) and the stakeholder attribute value (A). ViII is obtained by observing the interest (v) and impact (i) index rated on likert scale ranging from 1 to 5 with given (1).

$$\text{ViII} = \frac{\text{vi}}{25}$$

The Stakeholder attribute value is calculated through weighting using Superiority Chart Method to the Power, Legitimacy, and Urgency possessed by each sustainable related stakeholder [28]. The weighting of the attributes is done using the following (2), (3), and (4).

$$\text{Weight P} = \frac{p}{p+l+u}$$ (2)

$$\text{Weight L} = \frac{l}{p+l+u}$$ (3)

$$\text{Weight U} = \frac{u}{p+l+u}$$ (4)

The attribute possessed by each stakeholder determined by using Certain Index (CER) (5). The attributes are given to stakeholders with the CER value > 0,5.

$$\text{CER}_A(G_i) = \frac{\text{Si}}{N}$$

The factor of stakeholder influence levels (FoSIL) is the multiplication of the stakeholder attribute value and vested interest-impact index (6).

$$\text{FoSIL} = A \times \text{ViII} = A \times \sqrt{\frac{\text{vi}}{25}}$$ (6)

The fourth stage carried out with semi-structured interviews to identify the major role possessed by each stakeholder. The primary and secondary role carried by stakeholder is determined through quantification process from the stakeholder role in sustainable lean construction in the interview data.

The third and fourth involved 41 survey respondents and 10 interviews with representatives across various infrastructure project stakeholders mainly, government organizations, contractors, consultants, owners, suppliers, and architects.

The respondents and interviewees were selected through purposive sampling with a requirement of minimum of two years of working in the construction industries and have a working or research experiences in sustainable or lean construction-related topics or a user of a sustainable or lean construction projects. Table II summarizes the profiles of the research study participants.
TABLE I: RESEARCH STAGES, METHODS, AND OBJECTIVES

<table>
<thead>
<tr>
<th>Stages</th>
<th>Methods</th>
<th>Objectives</th>
</tr>
</thead>
</table>
| 1            | Semi-Structured       | To identify the major stakeholder involved in decision making of sustainable and lean construction
|              | Interviews            | To validate the major stakeholder involved and evaluate the involvement that stakeholder possessed
|              |                       | To validate the research variable and indicators                           |
| 2            | Questionnaire Survey  | To fine-tune the initial questionnaire                                       |
|              |                       | To validate the measurement system that will be carried out on each stakeholder related to sustainable lean construction in Indonesia |
| 3            | Questionnaire Survey  | To determine the weight of each Stakeholder Attributes Value, Power (P), Legitimacy (L), and Urgency (U) |
|              |                       | To determine the Stakeholder Attributes Value possessed by each stakeholder related to sustainable lean construction in Indonesia |
|              |                       | To determine the vested interest levels (v), and the influence impact levels (i) on each stakeholder on likert scale ranging from 1 to 5 |
| 4            | Semi-Structured       | To identify the major role possessed by each stakeholder in sustainable lean construction decision-making process in Indonesia |
|              | Interviews            | To help the analysis process of the previous findings                       |

TABLE II: PROFILES OF THE RESEARCH PARTICIPANTS

<table>
<thead>
<tr>
<th>Stage</th>
<th>Stakeholder Group</th>
<th>No. Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Semi-Structured Interviews)</td>
<td>Contractor</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Academia</td>
<td>1</td>
</tr>
<tr>
<td>2 (Questionnaire Surveys)</td>
<td>Contractor</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Owner</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Supplier</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Government Organization</td>
<td>1</td>
</tr>
<tr>
<td>3 (Questionnaire Surveys)</td>
<td>Contractor</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Consultant</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Architect</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Supplier</td>
<td>3</td>
</tr>
<tr>
<td>4 (Semi-Structured Interviews)</td>
<td>Government Organization</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Owner</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Contractor</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Consultant</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Supplier</td>
<td>1</td>
</tr>
</tbody>
</table>

IV. DATA ANALYSIS AND RESULTS

From the process of literature study, identified seven stakeholder groups that have a great influence on decision-making in sustainable and lean infrastructure construction in Indonesia, namely government organizations, owners, consultants, contractors, architects, suppliers, and non-governmental organizations. Through semi-structured variable validation interviews and pilot studies, non-governmental organizations do not have a significant influence on decision making and NGOs are not included in this study.

The results of the 41 respondents weighting the ratio of P, L, and U then calculated using the superiority chart method. The rating of the P, L, and U is calculated using through sum of the R_{xy} from power, legitimacy, and urgency. The weight of each attribute is the average of the weight of P, L, and U from respondents. Table III summarize the weight of the stakeholder attributes. The result shows the weight of P 0.338, L 0.344, and U 0.317.

TABLE III: SUPERIORITY CHART WEIGHTING

<table>
<thead>
<tr>
<th>Value</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating P</td>
<td>1.524</td>
</tr>
<tr>
<td>Rating L</td>
<td>1.549</td>
</tr>
<tr>
<td>Rating U</td>
<td>1.427</td>
</tr>
<tr>
<td>Weight P</td>
<td>0.339</td>
</tr>
<tr>
<td>Weight L</td>
<td>0.344</td>
</tr>
<tr>
<td>Weight U</td>
<td>0.317</td>
</tr>
</tbody>
</table>

The attribute possessed by the stakeholder is obtained through a certainty index. The attribute possessed by stakeholders is assessed by each respondents representing the company’s view of the stakeholders. The results the stakeholder attribute possessed by each stakeholder determined if the value obtained by the CER_{A(G)} is more than 0.5, then there is an attachment between stakeholders with these attributes. The results of the stakeholder attribute value (A) of each stakeholder are summarized in Table IV.

TABLE IV: CERTAINTY INDEX OF EACH STAKEHOLDER

<table>
<thead>
<tr>
<th>Group</th>
<th>P</th>
<th>CER</th>
<th>L</th>
<th>CER</th>
<th>U</th>
<th>CER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government</td>
<td>0.902</td>
<td>✓</td>
<td>0.732</td>
<td>✓</td>
<td>0.512</td>
<td>✓</td>
</tr>
<tr>
<td>Owner</td>
<td>0.902</td>
<td>✓</td>
<td>0.756</td>
<td>✓</td>
<td>0.439</td>
<td>✓</td>
</tr>
<tr>
<td>Contractor</td>
<td>0.341</td>
<td>✓</td>
<td>0.732</td>
<td>✓</td>
<td>0.659</td>
<td>✓</td>
</tr>
<tr>
<td>Consultant</td>
<td>0.220</td>
<td>✓</td>
<td>0.732</td>
<td>✓</td>
<td>0.634</td>
<td>✓</td>
</tr>
<tr>
<td>Architect</td>
<td>0.098</td>
<td>✓</td>
<td>0.659</td>
<td>✓</td>
<td>0.561</td>
<td>✓</td>
</tr>
<tr>
<td>Supplier</td>
<td>0.049</td>
<td>✓</td>
<td>0.537</td>
<td>✓</td>
<td>0.659</td>
<td>✓</td>
</tr>
</tbody>
</table>

The Vested Interest Impact Index (VII) is calculated from the mean values of the vested interest levels (v) and the influence impact levels (i) calculated from each stakeholder group. Table VI summarized the mean value of interest and impact each stakeholder possessed in each sustainability criteria.

The Vested Interest Impact Index deliver a stakeholder mapping based on the level of interest and impact that stakeholder have on sustainable infrastructure construction. From the stakeholder mapping, all stakeholder, government organizations, owners, consultants, contractors, architects, and suppliers have a high level of impact and interest in sustainable related issue. Fig. 1 shows the stakeholder mapping of the overall sustainability lean related criteria by each stakeholder.

The factor of stakeholder influence levels (FoSIL) is calculated by multiplying the stakeholder attributes value (A) and the vested interest impact index possessed by each stakeholder (VII) related to the sustainable infrastructure in Indonesia. The results of the FoSIL value of each stakeholder are summarized in Table VII.

From the interview in the fourth stage, the major and secondary role is determined through quantification of the role possessed by stakeholder from each interview data on all sustainability criteria. sustainability criteria.

The major role is showed by the high number of roles mentioned by the interviewees in each. From the interview, it was found that there are 7 major roles of stakeholder in the implementation of sustainable and lean construction, mainly regulator, stimulator, initiator, broker/mediator, concept refiner, context enabler, and provider. Table V summarize the
major and secondary role of stakeholder in decision-making sustainable infrastructure in Indonesia.

There is a relationship between the level of stakeholder influence in decision-making as shown in the factor of stakeholder influence level and the major role that stakeholders have in sustainable lean construction. This hypothesis is proven by the fulfillment of the chi square correlation test criteria where the value of \( r_{\text{count}} \) is greater than the \( r_{\text{table}} \) with a significance value less than 0.005. Obtained from the calculation, the value of the person chi square of \( r_{\text{count}} \) is 991.983 with a significance value of 0.000. This prove that there is a relationship between the two variables and shows that the greater the influence, the greater the role in the decision-making by stakeholders.

![Stakeholder mapping on overall sustainability criteria.](image)

**Fig. 1. Stakeholder mapping on overall sustainability criteria.**

Table VII shows that the government organizations have the highest level of stakeholder influence as indicated by owning the highest FoSIL value. Owners have the second rank of importance, the third is consultant, the fourth is contractor, the fifth is architect, and the sixth is supplier.

### TABLE VI: THE VALUE OF THE INTEREST AND IMPACT POSSESSED BY EACH STAKEHOLDERS

<table>
<thead>
<tr>
<th>Criteria</th>
<th>INTEREST VALUE</th>
<th>IMPACT VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Government</td>
<td>Owner</td>
</tr>
<tr>
<td>Land Usage</td>
<td>3.667</td>
<td>4.091</td>
</tr>
<tr>
<td>Water Efficiency</td>
<td>3.333</td>
<td>4</td>
</tr>
</tbody>
</table>

### TABLE VII: THE VALUE OF OVERALL FACTOR OF STAKEHOLDER INFLUENCE LEVEL

<table>
<thead>
<tr>
<th>Group</th>
<th>Attributes</th>
<th>Stakeholder Influence</th>
<th>Overall Factor of Stakeholder Influence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>L</td>
<td>U</td>
</tr>
<tr>
<td>Government</td>
<td>0.339</td>
<td>0.344</td>
<td>0.317</td>
</tr>
<tr>
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### A. The Major Role and Influence of Government Organizations

When you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables.

The government has the power, legitimacy, and urgency to implement sustainable and lean construction in Indonesia. The government also has the highest ViII level that indicates the implementation of lean construction on infrastructure projects in Indonesia is highly influenced by the Indonesian government organizations. Every policy made by the government as regulations and rules have to be fulfilled by all stakeholders. Every decision about infrastructure management, usage of materials, and use of technology made by the government organizations will determine the level of the implementation of sustainable and lean construction in Indonesia.

The government organizations have a major role as a regulator in the implementation of sustainable lean construction on infrastructure projects in Indonesia. The government has a role to make regulations and rules that will be implemented by all project stakeholders. Standards that made by the government organizations serve as a reference or base for design, movement, procurement, and project management. Regulation made by the government have a tendency to force project stakeholders to implement what is in the regulations, including sustainable construction regulations. With the development of sustainable and lean
construction regulation in Indonesia, it will clarify the flow of the implementation of lean construction by infrastructure project stakeholders. In addition to regulations, the incentives provided by the government also have to be sufficient and should not be complicated to follow.

**B. The Major Role and Influence of Owners**

The infrastructure project owners have the second highest FoSIL, one level directly under the government organizations. This shows that the infrastructure project owners have the highest decision-making capability and authority in the implementation of sustainable and lean construction. The project owner has the highest level of influence as all design criteria and acceptance criteria of the infrastructure project made by the owner have to fulfill by all infrastructure project stakeholders. By including the criteria of the use of sustainable lean construction in the employer information requirements, project stakeholders have to develop and use the principles and tools of sustainable and lean construction in the infrastructure projects.

Owners have a major role as a stimulator in the implementation of sustainable lean construction in infrastructure projects. The role of stimulator is to stimulate the project stakeholders to fulfill all the needs of the project owner, including the need of the implementation of sustainable principals. Owner as a stakeholder that understand the criteria and expected results from the infrastructure construct projects have a role to understand and develop a lean construction concept and criteria that will be applied to the project. Owner can request all project stakeholders to implement sustainable and lean principles through employer information requirements document. By implementing lean principles on the employer requirement document, all stakeholders will be forced to make a action plan with sustainable and lean principles.

**C. The Major Role and Influence of Consultants**

The consultants have the third highest FoSIL level. This value shows that consultants, including management consultants and structural consultants, have an important role in supporting and implementing sustainable lean construction in the project planning phase. Consultants in collaboration with architects have a role to fulfill the project design criteria requested by the infrastructure project owner. Moreover, the consultant’s encouragement to the owner from the beginning of the project planning phase can minimize one of many obstacles in implementing sustainable and lean principles in the construction industry, as the lack of knowledge and interest of the owner to implement the sustainable and lean construction on infrastructure projects.

The design consultant has a main role as a concept refiner. The design consultant in a collaboration with architect’s act as concept refiner to design the infrastructure systems and the implications of lean construction in the operational infrastructure processes. The consultant plays a big role in determining the level of implementation of sustainable design from the very beginning of the infrastructure project as in the planning stage. The design consultant will determine the sustainability implemented through structural design and the selection of material types to support sustainability.

**D. The Major Role and Influence of Contractors**

Contractors have fourth rank of stakeholder influence rating. The level of the influence indicates that the contractor has a less power and impact on the decision-making in implementing sustainable lean construction. There are differences in the level of vested interest and vested impact between state-owned contractors (BUMN) and private contractors. BUMN contractors have a higher level of interest than private contractors and are willing to implement sustainable lean construction. This proven by the fact that several BUMN contractors already have a sustainable construction and lean construction development division and will begin to implement it massively in the next few years. This is exacerbated by the contractor is not having the power to force the implementation of lean construction from project owners as contractors only have the ability to propose a lean construction system to the project owners.

Contractors have a role as a context enabler. A context enabler has a role to execute the design made by the owner in collaboration with design consultant and architect. Contractors have a role to integrate lean construction tools, such as BIM in the infrastructure construction phase. In addition to having a role as a context enabler, contractors have a secondary role as a concept refiner to develop and propose a review design planning based on existing field condition and integrated with lean planning. In some projects, the contractors also have a main role as a concept refiner to develop the infrastructure design as a design planner.

**E. The Major Role and Influence of Architects**

Architects have the second lowest FoSIL, one above suppliers. The low level of influence is shown in planning stage of infrastructure construction projects, architects have less interest and impact in decision-making of implementing sustainable and lean related to the construction processes. Architects only have a role to fulfill the aesthetics and the design of the infrastructure according to the criteria given by the owner.

Architects have a major role as a concept refiner. Architect in collaboration with design consultant have a role to integrate the principal of sustainable and lean construction in the design planning phase. Despite having a same role as a design consultant, architects will apply the concept of sustainable and lean construction in architectural systems of the infrastructure projects.

**F. The Major Role and Influence of Suppliers**

The suppliers have the lowest FoSIL which indicates construction projects suppliers have the lowest level of influence in decision-making of the implementation of sustainable lean construction in infrastructure projects. The value of the influence level indicates that the supplier has a limitation to support lean construction to the parties who are directly related or contractually bound to suppliers, whis is usually the contractor.

The construction suppliers have a primary role as a materials, tools, and technologies provider in the infrastructure projects. Supplier also have a significant role to provide the material and technology specification to the contractors and owner. This specification will allow the project owner and contractor to develop a sustainable and
lean principle. The supplier also has a role in creating a production system with a pull principle and a lean procuring material on time and on the right place.

G. A Correlation between Stakeholder Role and Stakeholder Influence Levels

The fulfillment of the chi square test correlation criteria where the $F_{\text{count}}$ is greater than the $F_{\text{table}}$ with a significance value of 0.005 is proving that there is a relationship between the stakeholder role and the stakeholder influence level in implementing sustainable lean construction in infrastructure construction projects. This correlation shows that the higher the stakeholder’s role, the greater the stakeholder’s power. The government organization as a regulator has the biggest power in the implementation of the sustainable lean infrastructure construction. This shows the role of the regulator has the power to regulate and force the infrastructure stakeholders to follow the regulation made by the government organizations. In the legitimacy and urgency attributes, the regulator has the highest legitimacy and urgency compared to other stakeholders. On the other hand, the supplier as a provider has the least power as supplier only provides the need of technology needed by the contractors and owners.

In the interest-impact attribute, the correlation between the level of influence and the role of the stakeholder shows the higher the level of influence, the higher the stakeholder interest-impact level. This is supported by the incentives provided by the government increase the interest of the infrastructure stakeholder to implement the principles of lean construction. In addition to incentives, the increase in in the company name or company brand as a positive impact from implementing sustainable lean construction is one of the driving factors for the implementation of sustainable and lean construction in infrastructure projects.

The relationship between the level of influence and the role of the stakeholder in implementing sustainable lean construction shows that the higher the role of the stakeholder, the higher the level of influence possessed by the stakeholder. This shows that in order to increase the level of influence carried by the stakeholder, infrastructure project stakeholder can adopt the role of the stakeholder with a level of influence above them. To increase the level of influence possessed by the owner who has a major role in stimulator, the project owner can adopt the major roles of the regulator. One form of the adaptation project can be done by the project owner is to make a regulation and company standards that will become a reference for structural designers and architects who have a major role in concept refiners.

V. CONCLUSIONS

This paper shows that the government organization has the highest level of influence in all the sustainable lean construction criteria which is based on Ministry of PUPR Regulation No. 9 of 2021. Infrastructure project owner has the second highest level of influence. While the consultants are ranked 3rd, contractors are ranked 4th, architects are ranked 5th, and the suppliers are ranked 6th. This paper also shows that there are 7 roles that project stakeholders have in implementing sustainable construction that intersect with lean construction principles, that is provider, context enabler, concept refiner, broker/mediator, initiator, stimulator, and regulator. There is a positive relationship between the level of influence of stakeholder and the role of stakeholder in decision-making of the implementation of lean construction. This indicates that the higher the level of role possessed by stakeholders, the greater the influence that stakeholder have in implementing lean construction in Indonesia.

To increase the level of influence that stakeholder possessed in decision-making on the implementation of sustainable lean construction in infrastructure construction projects, stakeholder could adapt the roles held by the stakeholder with a higher level of influence. The government as the stakeholder with the highest level of influence has a major role as a regulator and expected to make regulator to force the implementation of sustainable and lean construction in Indonesia.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

ABA and FM conceptualized this study, ABA and FM funded the research, ABA investigated the problem and methodology, ABA and FM conducted the research, FM supervised this study, ABA visualized the results, ABA and FM wrote the original draft, ABA completed the paper in English, ABA and FM reviewed and edited the final paper.

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REFERENCES


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