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

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***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 National Statistic Agency (BPS) in Indonesia, in 2020 Indonesia experienced an aggregate economic contraction of −2,07% from 2019.

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 shows 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 sustainablity 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 componen 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 Repulic 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 understading 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 exsisting environmental system from damage caused by construction activities. Some aspect that can be review 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 bu 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, inverstment 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 fuction that initiate changes in various economic variables, such as changes in company costs and home utilities [15]. Urban infrastructure fuction 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, wailways, airports, clean water infrastructure, and may others. There are three categories, that is Institutional Infrastructure, Personal Infrstructure, 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

infrastructure, which aims to identify the needs and impacts from infrastructure construction on biotic and abiotic systems [17]. Sustainable infrastructure is one kind of fulfilling the Sustainable Development Goals (SDG) 9, industry, innovation, and infrastructure. Its because the development of sustainable infrastructure is fundamentally needed to connect the relation between another SDG [18].

Transportation related infrastructure, including toll roads, has a very high impact on economic circulation. Connecting infrastructure such as toll roads has a function to connect the primary or informal community sector with the secondary or formal community sector. One form of the implementation of sustainable infrastructure in transportation related infrastructure is to use sustainable materals in the planning, design, and construction of highway infrastructure.

C. Lean Construction

Lean construction is an alternative approach to construction management that aims to improve construction performance and productivity by minimazing material waste, time, labor and effort, and increasing maximum value given to the user from the construction process [19]. Lean also means producing products by placing production order in the process at the right time, place, and amount and being flexible to future change [20].

Lean construction is a management system adopted from a car manufacturing company, that is the Toyota Production System (TPS). Inside the Toyota Production System also included a control framework called Total Quality Control (TQC) that applied in conjunction with TPS to reduce waste and defects in the manufacturing process. Toyota wah has a pyramid model that correspond the 14 principals of TPS.

Lean construction offers the basic concept of sustainability that has the potential to produce new methods and technologies that can encaurage sustainable concept [21]. By integrating lean constructioin with sustainable construction, there will be achieved better environmental impacts, and reduced waste and cost of construction. Lean construction and sustainable construction can be connected through a sustainable lean construction framework by linking the sustainability principles that have an impact on the aspect of lean construction [22]. This framework links the foundations of sustainability related to lean construction. The value engineering of the project is developed in each project life cycle from designing, estimating, initial planning, scheduling, constructing, and completing.

Currently, the implementation of lean construction I Indonesia is still very rare. This can be happened because constructioin companies in Indonesia believe that adapting lean construction will require a lot of money to train company staff to meet the requirements [23]. Moreover, Indonesia contractors have a low level of awareness and ability to use lean construction tools and techniques.

There are many drivers and barriers in lean construction adaptation. The main driving factors of the implementation of lean construction are improved quality of work, safety, productivity, control process, material, and human planning caused from adapting lean construction. This can be achieved because lean construction is the principle of priotizing the value of the project and increasing efficiency. However, there are factors that prevent stakeholders from adopting lean construction in construction projects. Factors that severely restraint stakeholder from implementing lean construction are the lack of worker's attitudes towards lean construction, the ability of workers in lean construction, lack of company commitment, and poor management attitudes.

D. Stakeholder Management

Stakeholder is an individual, group, or organization who can influence or be influenced by the decisions, activities, or outcomes of a project, program, or portfolio. Stakeholder management consists of identifying, planning, manganing, and monitoring stakeholder management [24].

1) Identify stakeholder

Identify stakeholder is a process of identifying or recognizing stakeholder about their importance, involvement, dependence, influence, and impact to the project. This process will deliver a stakeholder register which consist of stakeholder information, stakeholder assessment, and stakeholder classification. After the stakeholder are categorized. An impact/interest grid is created, the role of each stakeholder will be determined, including players, subjects, context setters, and crowds.

In addition with using the power-interest grid or impact-interest grid, there is a measurement method using the Factor of Stakeholder Influence Level (FoSIL), that is the stakeholder engagement analysis method developed by Olander [25]. The use of FoSIL is a development of the power-interest matrix by calculating the attributes of power, legitimacy, urgency, interest, and impact of each stakeholder.

2) Plan stakeholder engagement

Plan stakeholder engagement is the process of developing a stakeholder engagement plan in the project decision-making process based on needs, expectations, interests, and impacts on the project. The plan stakeholder engagment stage also plan the approaching method of each stakaeholder. Appropriate approaching method is very important to increase stakeholder engagement. The approaching method consist of manage closely, keep satisfied, keep informed, and monitor.

3) Manage stakeholder engagement

Manage stakeholder engagement is the process of communication and stakeholder engagement planning to meet their needs, expectations, interest, and concern, address existing issues and encourage stakeholder engagement.

4) Monitor stakeholder engagement

Monitor stakeholder engagement is the process of monitoring or observing the project stakeholder relationships and adjusting the appropriate strategies to increase the stakeholder engagement. This process is carried to analyze whether any adjustments are needed to the current and desired stakeholder engagement level [26].

In order to achirve sustainable construction in developing countries, there is 6 processes that can be carried out by the infrastructure stakehodlers [27]. The 6 key processes are namely identifying all key stakeholders, connecting all stakeholders with sustainability targets, making stakeholder priorities, managing stakeholder engagament, measuring stakeholder performance, and realizing target into actions.

In case of the infrastructure construction, there are many

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, generallya 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 implmenentation 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 efficien 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 questionaire survey and interview questions.

A questionaire 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 intented 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).

$$ViII = \sqrt{\frac{v \times i}{25}} \tag{1}$$

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).

$$Weight\ P = \frac{P}{P+L+U} \tag{2}$$

$$Weight\ L = \frac{L}{P+L+U} \tag{3}$$

$$Weight\ U = \frac{U}{P+L+U} \tag{4}$$

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

$$CER_A(G_i) = \frac{O_A^+}{N} \tag{5}$$

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

$$FoSIL = A \times ViII = A \times \sqrt{\frac{v \times i}{25}} \tag{6}$$

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 stakholders 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

Stages	Methods	Objectives
1	Semi-Structured Interviews	To identify the major stakeholder involved in decision making of sustainable and lean construction To validate the major stakeholder involved and evaluate the involvement that stakeholder possessed To validate the research variable and indicators
2	Questionaire Survey	To fine-tune the initial questionaire To validate the measurement system that will be carried out on each stakeholder related to sustainable lean construction in Indonesia
3	Questionaire 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 Interviews	To identify the major role possessed by each stakeholder in sustainable lean construction decision-making process in Indonesia To help the analysis process of the previous findings

TABLE II: PROFILES OF THE RESEARCH PARTICIPANTS

Stage	Stakeholder Group	No. Respondents
1 (Semi-Structured Interviews)	Contractor	1
	Academia	1
	Owner	1
2 (Questionaire Surveys)	Contractor	3
	Owner	5
	Supplier	1
	Government Organization	1
3 (Questionaire Surveys)	Government Organization	3
	Owner	12
	Contractor	17
	Consultant	5
	Architect	1
	Supplier	3
4 (Semi-Structured Interviews)	Government Organization	1
	Owner	1
	Contractor	5
	Consultant	1
	Supplier	1

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-government 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

Value	Average
Rating P	1,524
Rating L	1,549
Rating U	1,427
Weight P	0,339
Weight L	0,344
Weight U	0,317

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 $CER_A(G_i)$ is more than 0,5, then there is an attatchment 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

Group	P	CER	L	CER	U	CER
Government	0,902	✓	0,732	✓	0,512	✓
Owner	0,902	✓	0,756	✓	0,439	
Contractor	0,341		0,732	✓	0,659	✓
Consultant	0,220		0,732	✓	0,634	✓
Architect	0,098		0,659	✓	0,561	✓
Supplier	0,049		0,537	✓	0,659	✓

The Vested Interest Impact Index (ViII) 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 (ViII) 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.

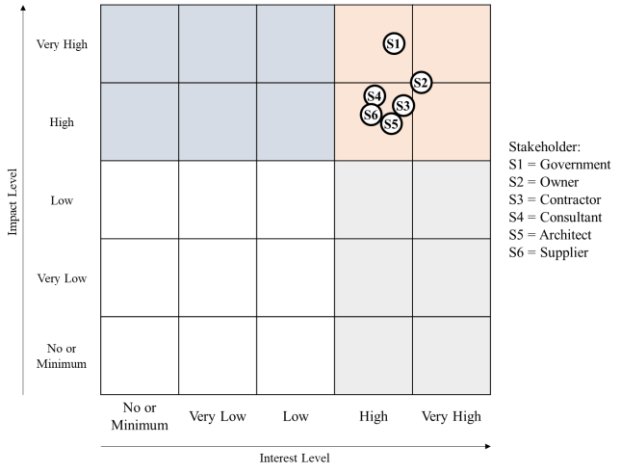

Fig. 1. Stakeholder mapping on overall sustainability criteria.

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_{count} is grater than the r_{table} with a significance value less than 0,005. Obtained from the calculation, the value of the person chi square of r_{count} is 991,983 with a significance value of 0,000. This prove that there is a relationship betweet the two variables and shows that the greater the influence, the greater the role in the decision-making by stakeholders.

TABLE V: MAJOR AND SECONDARY ROLE OF STAKEHOLDER

No	Stakeholder	Major Role	Secondary Role
1	Goverment	Regulator	Broker / mediator
2	Owner	Stimulator	Concept refiner
3	Consultant	Concept refiner	Initiator
4	Contractor	Context enabler	Concept refiner
5	Architect	Concept refiner	Context enabler
6	Supplier	Provider	Context enabler

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 contrator, the fifth is architect, and the sixth is supplier.

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

Criteria	INTEREST VALUE						IMPACT VALUE					
	Government	Owner	Contractor	Consultant	Architect	Supplier	Government	Owner	Contractor	Consultant	Architect	Supplier
Safety and Health	4,889	4,303	4,157	3,917	4	3,444	5	4,455	3,804	4	3,667	3,778
Sustainable Design	3,5	4,091	4,324	4,5	4,5	4,167	4,167	4,136	4,176	4,125	4	4,167
End-User	3,333	4,318	3,529	3,625	3,5	3,333	4,333	4,318	3,559	3,875	3,5	3,5
Land Usage	3,667	4,091	4,029	3,75	3,5	4	4,333	3,864	4	3,375	4	4
Energy Efficiency	3,667	4,091	3,382	3,25	4	4,333	4,833	4,091	3,324	3,25	3	4
Water Efficiency	3,333	4	3,176	3,875	3	2,667	4,333	3,955	3,088	3,75	3	2,333
Material Efficiency	4,083	4,091	3,971	4,042	3,583	3,556	4,528	3,947	3,922	3,854	3,417	3,333
Mean	3,947	4,127	3,88	3,93	3,68	3,6	4,533	4,058	3,791	3,8	3,48	3,493

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

Overall Factor of Stakeholder Influence Level									
Group	Attributes				Stakeholder Influence				
	P	L	U	a	v	i	ViII	FoSIL	Rank
Government	0,339	0,344	0,317	1,000	3,947	4,533	0,846	0,846	1
Owner	0,339	0,344	0,000	0,683	4,127	4,058	0,819	0,559	2
Contractor	0,000	0,344	0,317	0,661	3,880	3,791	0,767	0,507	4
Consultant	0,000	0,344	0,317	0,661	3,930	3,800	0,773	0,511	3
Architect	0,000	0,344	0,317	0,661	3,680	3,480	0,716	0,473	5
Supplier	0,000	0,344	0,317	0,661	3,600	3,493	0,709	0,469	6

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 implmenetation 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 rulesthat 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 infastructure 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 infastructure constructure 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 colaboration with architect's act as concept refiner to design the infrastructure systems and the implications of lean constuction 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 has a role as a context enabler. A context enabler has a role to execute the design made by the owner in colaboration with design consultant and architect. Contractors have a role to integrate lean construction tools, such as BIM in the infrastructue 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 lovest 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 aestethics 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 spesification 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 r_{count} is greater than the r_{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 higheset 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 posessed 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 posessed 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 that project can be done by the project owner is to make a reagulation 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 posessed by stakeholders, the grater the influence that stakeholder have in implementing lean construction in Indonesia.

To increase the level of influence that stakeholder posessed 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

[1] R. M. Reffat, "Sustainable construction in developing countries," in *Proc. First Archit. Int. Conf. Cairo Univ. Egypt*, pp. 1–8, 2004.

[2] I. Suswita, D. Damanik, and P. D. Panjaitan, "Pengaruh Infrastruktur terhadap Pertumbuhan Ekonomi di Kabupaten Simalungun," vol. 2, no. 1, 2020.

[3] E. Eyiah-Botwe, C. Aigbavboa, and W. Thwala, "Mega Construction Projects: using stakeholder management for enhanced sustainable construction," *Am. J. Eng. Res.*, no. 5, pp. 80–86, 2016.

[4] A. Feige, H. Wallbaum, S. Krank, A. Feige, H. Wallbaum, and S. Krank, "Harnessing stakeholder motivation : Towards a Swiss sustainable building sector Harnessing stakeholder motivation : towards a Swiss sustainable building sector," vol. 3218, no. February, 2016, doi: 10.1080/09613218.2011.589788.

[5] T. M. W. Mak, P. C. Chen, L. Wang, D. C. W. Tsang, S. C. Hsu, and C. S. Poon, "A system dynamics approach to determine construction waste disposal charge in Hong Kong," *J. Clean. Prod.*, vol. 241, 118309, 2019, doi: 10.1016/j.jclepro.2019.118309.

[6] Y. Wang, Q. Han, B. de Vries, and J. Zuo, "How the public reacts to social impacts in construction projects? A structural equation modeling study," *Int. J. Proj. Manag.*, vol. 34, no. 8, pp. 1433–1448, 2016, doi: 10.1016/j.ijproman.2016.07.008.

[7] K. C. Goh and J. Yang, "Importance of sustainability-related cost components in highway infrastructure: perspective of stakeholders in Australia," *J. Infrastruct. Syst.*, vol. 20, no. 1, 04013002, 2014, doi: 10.1061/(asce)is.1943-555x.0000152.

[8] R. Sacks, L. Koskela, B. A. Dave, and R. Owen, "Interaction of lean and building information modeling in construction," *J. Constr. Eng. Manag.*, vol. 136, no. 9, pp. 968–980, 2010.

[9] S. L. Slocum, "The viable, equitable and bearable in Tanzania," *Tour. Manag. Perspect.*, vol. 16, pp. 92–99, 2015, doi: 10.1016/j.tmp.2015.07.012.

[10] G. Ding and P. J. Forsythe, "Sustainable construction: Life cycle energy analysis of construction on sloping sites for residential

buildings," *Constr. Manag. Econ.*, vol. 31, no. 3, pp. 254–265, 2013, doi: 10.1080/01446193.2012.761716.
[11] R. Valdes-Vasquez and L. E. Klotz, "Social Sustainability considerations during planning and design: framework of processes for construction projects," *J. Constr. Eng. Manag.*, vol. 139, no. 1, pp. 80–89, 2013, doi: 10.1061/(asce)co.1943-7862.0000566.
[12] M. Yılmaz and A. Bakış, "Sustainability in construction sector," *Procedia - Soc. Behav. Sci.*, vol. 195, pp. 2253–2262, 2015, doi: 10.1016/j.sbspro.2015.06.312.
[13] T. Y. M. Lam, "Driving sustainable construction development through post-contract key performance indicators and drivers," no. 2010, 2020, doi: 10.1108/SASBE-07-2020-0111.
[14] R. J. Yang, P. X. W. Zou, and J. Wang, "Modelling stakeholder-associated risk networks in green building projects," *Int. J. Proj. Manag.*, vol. 34, no. 1, pp. 66–81, 2015, doi: 10.1016/j.ijproman.2015.09.010.
[15] W. Buhr, "What is infrastructure?," *Volkswirtschaftliche Diskuss.*, pp. 107–03, 2003.
[16] F. Bourguignon and B. Pleskovic, *Annual World Bank Conference on Development Economics 2005*, The World Bank, 2005.
[17] J. Ahern, "Green infrastructure for cities: The spatial dimension," *Cities Futur. Towar. Integr. Sustain. Water Landsc. Manag.*, 2007.
[18] S. Thacker *et al.*, "Infrastructure for sustainable development," *Nat. Sustain.*, vol. 2, pp. 324–331, 2019, doi: 10.1038/s41893-019-0256-8.
[19] S. Gao and S. P. Low, *Lean Construction Management*, 2014.
[20] M. P. da Silva, G. L. Tortorella, and F. G. Amaral, "Psychophysical demands and perceived workload—an ergonomics standpoint for lean production in assembly cells," *Hum. Factors Ergon. Manuf.*, vol. 26, no. 6, pp. 643–654, 2016, doi: 10.1002/hfm.20404.
[21] A. H. A. Jamil and M. S. Fathi, "The integration of lean construction and sustainable construction: A stakeholder perspective in analyzing sustainable lean construction strategies in Malaysia," *Procedia Comput. Sci.*, vol. 100, pp. 634–643, 2016, doi: 10.1016/j.procs.2016.09.205.
[22] M. Scherrer-Rathje, T. A. Boyle, and P. Deflorin, "Lean, take two! Reflections from the second attempt at lean implementation," *Bus. Horiz.*, vol. 52, no. 1, pp. 79–88, 2009, doi: 10.1016/j.bushor.2008.08.004.
[23] H. Prayuda, F. Monika, M. D. Cahyati, Hermansyah, B. Afriandini, and D. Budiman, "Critical review on development of lean construction in Indonesia," in *Proc. 4th Int. Conf. Sustain. Innov. 2020–Technology, Eng. Agric. (ICoSITEA 2020)*, vol. 199, no. ICoSITEA 2020, pp. 83–88, 2021, doi: 10.2991/aer.k.210204.018.
[24] P. Project management Instituite, *A Guide to the Project Management Body of Knowledge (PMBOK® Guide) (6th Edition)*, 2017.
[25] S. Olander, "Stakeholder impact analysis in construction project management," *Constr. Manag. Econ.*, vol. 25, no. 3, pp. 277–287, 2007, doi: 10.1080/01446190600879125.
[26] M. Wu, *Chapter 10 Sustainability as Stakeholder Management*, vol. 3. Emerald Group Publishing Ltd, 2011.
[27] M. Bal, D. Bryde, D. Fearon, and E. Ochieng, "Stakeholder Engagement: Achieving Sustainability in the Construction Sector," *Sustain.*, vol. 5, no. 2, pp. 695–710, 2013, doi: 10.3390/su5020695.
[28] [H. Li, S. T. Ng, and M. Skitmore, "Stakeholder impact analysis during post-occupancy evaluation of green buildings—a Chinese context," *Build. Environ.*, vol. 128, no. November 2017, pp. 89–95, 2017, doi: 10.1016/j.buildenv.2017.11.014.