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Sustainable construction practices in the execution of infrastructure projects

The extent of implementation

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Abstract

Purpose – In responding to global issues of creating sustainable development, the Indonesian government has enacted regulations (i.e. Ministry of Public Works and Housing No. 05/PRT/M/2015) on the implementation of sustainable construction in infrastructure project execution. The purpose of this paper is to evaluate the means of implementing sustainable principles in the execution of infrastructure projects in Indonesia by the main construction service providers and their partners. A lesson-learned is presented as a source of knowledge to underpin the extensive implementation of sustainable principles in the construction of infrastructure projects leading to an integrated approach in creating a sustainable infrastructure that fulfills the requirements of sustainable development.

Design/methodology/approach – The method used is questionnaire surveys with Indonesian construction practitioners who are working on building construction, road and bridge construction, water facilities construction and house and settlement construction.

Findings – From the results, the practices of sustainability principles by construction service providers in infrastructure project execution are imperative from the project procurement phase. The evaluation continues to the phase of construction project execution, which reveals the inconsiderable performance of sustainability indicators due to current constraints on the implementation of sustainability principles.

Originality/value – This research looks into the existing gaps between sustainable construction principles and their practical implementation in Indonesian infrastructure projects. This will foster a holistic approach in the practice of undertaking sustainable procurement processes, thus reinforcing project management techniques in the phase of sustainable construction project execution. This also strengthens the interrelated roles and responsibilities of project stakeholders by taking into account principles of safety, balance and the harmony of infrastructure and the environment.

Keywords Sustainable construction, Sustainable development, Infrastructure, Procurement indicators, Project execution indicators, Indonesia

Paper type Research paper

Introduction

Infrastructure development is part of national development and can be a driver of economic growth, both locally, regionally and nationally. The success of such development is one of the critical factors in generating a better economy, which can improve the welfare of the community

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and play a role in creating sustainable development. Sustainable development is development that enables the present to meet its own needs while supporting future generations to meet their needs (WCED, 1987); this definition is mostly used to figure out the conceptual frameworks for sustainable development (Abrahams, 2017). In today's practice, sustainable development was broadly introduced not just to encompass economic, social and environmental factors (Stead and Stead, 2014; Shurrab *et al.*, 2019) for the benefit of human development (Byrch *et al.*, 2007) and in order to improve the quality of human life, but also in relation to policies for sustainable development in the area of cultural empowerment (Froner, 2017), the principle of sustainable development within spatial planning regulations (Klimas and Lideika, 2018) and engineering education strategies to commit to the development of sustainable development (Takala and Korhonen-Yrjänheikki, 2019). Meanwhile, the concept of sustainable development, which is supported by sustainable infrastructure readiness, built using the concept of sustainable construction, is not yet well-known within the Indonesian construction industry.

Sustainable construction, therefore, is a way of ensuring that all construction activities are being carried out in a sustainable way, from the planning to the completion phases, while also considering the economic and social factors and the environmental impacts (Ismail *et al.*, 2017), since the construction industry has a direct influence on society, the environment and the economy (Agyekum-Mensah *et al.*, 2012; Xia *et al.*, 2015, 2016; Aghimien *et al.*, 2019) and has the greatest impact on sustainability compared to any other industrial sector. Even more than that, Oke *et al.* (2017) have stated that the construction industry plays an important role in preserving the indigenous environment through resource usage, asset utilization and water use and that the industry significantly contributes to improving the quality of human life (Shurrab *et al.*, 2019). In Indonesia, where the construction sector has become one of the leading indicators of national economic growth, sustainable construction is in urgent need of implementation. There is a basic regulation of the Indonesian Ministry of Public Works and Housing (No. 05/PRT/M/2015) relating to general guidelines for the implementation of sustainable construction in infrastructure project execution, to provide a direction for sustainable construction implementation that creates sustainable infrastructure, which will eventually contribute to sustainable development. However, there are still gaps between the regulations and their implementation in infrastructure construction projects. Meanwhile, the implementation of principles of sustainable construction has been spreading in neighboring countries, such as in Malaysia (Abd Hamid and Kamar, 2012) and promoted in other developing countries, particularly in Sri Lanka (Athapaththu and Karunasena, 2018) and Nigeria and South Africa (Aghimien *et al.*, 2019). The Malaysian construction industry has placed value on off-site manufacturing practices (i.e. environmental impacts and construction waste management) to contribute to sustainable construction (Abd Hamid and Kamar, 2012), Sri Lanka has focused on policies, resources and education for successful adoption of sustainability in its construction (Athapaththu and Karunasena, 2018), and Nigeria and South Africa have considered an awareness of using sustainable construction materials (Aghimien *et al.*, 2019). This paper, therefore, aims to evaluate the means of implementing sustainable principles in the execution of infrastructure projects in Indonesia by the main construction service providers and their partners. The evaluation covers selection of service providers, implementation of sustainable construction and constraints to the implementation of sustainable construction. New information was provided based on the discussion of the existing gaps between sustainable construction principles and their practical implementation in Indonesia as compared to other related countries.

Literature review

The construction sector in Indonesia plays an important role in providing regional infrastructure and human settlements. This sector is responsible for a large amount of resource use, both resources directly related to construction activities and others that affect or are affected by development activities, such as the environment, socio-economics and culture. This is in line with the issue of sustainable construction, to create physical facilities that meet economic, social and environmental objectives at present and in the future and fulfill the principle of sustainability. The Indonesian construction sector is still dealing with quality and competitiveness, by realizing that improving the quality of the process and the final product of construction is the first step toward sustainable development (CIB and UNEP-IETC, 2002).

The implementation of sustainable construction is important for the creation of sustainable infrastructure, which in turn, will contribute to sustainable development. The challenge of constructing infrastructure that meets the requirements of environmental management and sustainable development by taking into account the principles of benefit, safety, balance and harmony of infrastructure and the environment must be faced and responded to through the implementation of sustainable construction principles in the entire territory of the Republic of Indonesia. However, understanding and best practices of sustainable construction that have a positive impact on the environment, socioeconomics and culture must be clearly defined as sources of knowledge for construction industry stakeholders to be able to construct environmentally friendly infrastructures that also provide benefits for economic and social welfare. Moreover, according to Ismail *et al.* (2017), the implementation of sustainable construction methods in the project life-cycle, such as planning of land use, design of environmentally friendly projects, utilizing sustainable building materials, the efficient use of water or natural resources and production of minimal construction waste during the construction work can maximize the resiliency of housing development to disaster.

Fundamental characteristics of sustainable construction

With regard to any definition of sustainable issues in the construction industry, there are common focal points that link construction with sustainability aspects. Sustainable construction uses a holistic process to restore and maintain harmony between the natural and built environments, so that humans can live in a balanced economic environment (CIB and UNEP-IETC, 2002). Sustainable construction must be able to improve environmental objectives and integrate these with social and economic issues, to pursue quality of life, work efficiency and a healthy work environment (Abd Jamil and Fathi, 2016). In addition, sustainable construction emphasizes reductions in building energy use, both during the construction process and throughout the life of the operation of the buildings (Ismail *et al.*, 2017), with regard to materials employed (Oke *et al.*, 2017; Aghimien *et al.*, 2019) and waste production (Abd Jamil and Fathi, 2016).

Hill and Bowen (1997) noted that the term sustainable construction was originally developed to describe the responsibility of the construction industry to attain sustainability. Therefore, sustainable practices also take into account topics of safety, efficiency, productivity and waste minimization (Hall and Purchase, 2006; Koranda *et al.*, 2012; Abd Jamil and Fathi, 2016), in conjunction with the ecological, social and economic factors of a construction project (Kibert, 2008; Shurrab *et al.*, 2019). According to Agyekum-Mensah *et al.* (2012), the concept of sustainability in the construction industry has evolved over the years, from the preliminary focus on how to deal with the issue of inadequate resources, especially energy, to technical issues, such as materials, building components, construction technologies and energy-related design concepts termed “eco-build” and “green build” (Balasubramanian and Shukla, 2017). Furthermore, most recent authors emphasize that a strong and successful construction industry has a commitment to achieving social, environmental and economic success (Agyekum-Mensah *et al.*, 2012; Ndlangamandla and Combrinck, 2019). It is clear that sustainable construction has focused on how construction projects can preserve the environment and have an impact on the social and economic welfare of the community.

Requirements to implement sustainable construction

Successful implementation of sustainable construction principles, as espoused by its relevant definitions and characteristics, requires effective actions as well as the commitment of all parties who are involved in construction projects, including government, service providers and the community as users. It requires

(1) innovation and technology enhancement (Agyekum-Mensah *et al.*, 2012; Abd Jamil and Fathi, 2016; Oke *et al.*, 2017; Shurrab *et al.*, 2019);

(2) waste management strategy and practice (Tan *et al.*, 2011; Yates, 2013; Djokoto *et al.*, 2014);

(3) commitments to and knowledge of sustainable concepts which are transferred and adopted into new ways of working, thinking and learning to boost stakeholders' performance and motivation (Tan *et al.*, 2011; Sfakianaki, 2015; Abd Jamil and Fathi, 2016; Schröpfer *et al.*, 2017; Shurrab *et al.*, 2019);

(4) practices to be holistically applied throughout the organization rather than only in the projects (Koranda *et al.*, 2012);

(5) regulations of green practices for all types of projects, formally monitored for compliance (Shurrab *et al.*, 2019);

(6) mitigation of water wastage and enhancement of efficient water use in construction sites (Waidyasekara *et al.*, 2017);

(7) the positive contribution of project management knowledge and skills to sustainable construction, since project management is an essential prerequisite to the designing, delivering and managing of this environment (Agyekum-Mensah *et al.*, 2012; Ismail *et al.*, 2017);

(8) intra-organizational leadership in promoting sustainable construction practices throughout the organization by formulating policies, implementing procedures and disseminating best practices (Opoku *et al.*, 2015);

(9) a coordination of supply chain action in the construction sector (Sfakianaki, 2015; Balasubramanian and Shukla, 2017);

(10) training and investment in resource-efficient building methods and practices (Sfakianaki, 2015) and

(11) measurement tools, such as strategic metrics to analyze sustainable construction practices (Presley and Meade, 2010); rating systems to evaluate whether the construction project has a positive impact on the environment (Attallah *et al.*, 2013); and a buildings sustainable index to assess whether there is a potential improvement for the sustainable development of buildings in the long and short term (Hasan, 2016).

The requirements for implementing sustainable construction highlight the importance of budget allocation for education and training, a holistic approach to project management methodology and technology, all of which are supported by the interrelated roles and responsibilities of construction project stakeholders, to strongly ensure that construction projects are built based on sustainability principles. Nevertheless, given the requirements to attain sustainable construction, the implementation process can be a problematic one.

Barriers in the process of implementing sustainable construction

Many researchers in the area of sustainable construction implementation are of the opinion that the application of sustainable construction can face constraints. There are many barriers that prevent the construction industry, in both developed and non-developed countries, from implementing sustainability concepts (Hoffman and Henn, 2008; Ayarkwa *et al.*, 2010; Samari *et al.*, 2013; Abd Jamil and Fathi, 2016; Aghimien *et al.*, 2019). It is believed that the global construction industry will significantly benefit from adopting sustainable construction concepts; however, the implementation process is relatively sparse with slow progress (Samari *et al.*, 2013; Djokoto *et al.*, 2014; Abd Jamil and Fathi, 2016). The following are reviews on critical barriers to the implementation of sustainable construction practices, including why the requirements are difficult to implement.

Increased capital cost is the most significant barrier to the delivery of construction projects based on sustainable construction practices (Opoku and Ahmed, 2014; Karunasena *et al.*, 2016; Aghimien *et al.*, 2019). A tight construction budget has existed since the procurement phase, and this is something that hinders construction organizations from considering higher costs for infrastructure project execution. According to Upstill-Goddard *et al.* (2016), as construction service providers, small and medium-sized enterprises (SMEs) will take an interest in the implementation of sustainability standards if they see immediate financial benefits that meet their needs. SMEs' internal organization management shall allocate a budget from the project negotiation phase, as proof of their commitment in considering the requirements to implement sustainable construction.

In addition to the above barriers, Karunasena *et al.* (2016), in studying the integration of sustainability concepts and value planning for sustainable construction, found that it is not enough for the construction experts to only have good knowledge without being able to apply the concepts satisfactorily. Construction practitioners, including planning consultants and contractors, are the actors who have to be able to transfer their knowledge regarding the definitions of sustainable construction that support sustainable development into their application in project planning and execution. According to Abrahams (2017), the understanding of sustainable construction that supports sustainable development should be more extensive within the construction industry to ensure effective collaboration across the sector as a whole, hence, to improve the efficiency of the design, procurement and construction processes. Further to this view, most developing countries still practice unsustainable design and construction processes, which causes constant degradation of the environment (Abd Jamil and Fathi, 2016; Aghimien *et al.*, 2019). Additionally, other barriers that make sustainable construction difficult to implement by construction organizations are cultural barriers, lack of green technology and techniques, quality of specification, leadership and responsibility, stakeholder involvement, benchmarking systems (Sarhan and Fox, 2013; Samari *et al.*, 2013; Djokoto *et al.*, 2014; Froner, 2017) and safety, efficiency, productivity and waste minimization (Abd Jamil and Fathi, 2016). All these barriers should be overcome by paying attention to the requirements to implement sustainable construction and the actors of the construction industry having an intention to earnestly realize their important role in advancing current human well-being and that of future generations.

Research method

The understanding of which research methodologies and methods are appropriate is essential in the development of a framework for successful data collection in the construction industry (Abowitz and Toole, 2010). The research method, therefore, is a quantitative one and a survey questionnaire of Indonesian construction industry practitioners is employed, to collect opinions as well as empirical data regarding the evaluation of the way the main construction service providers implement sustainable principles in the execution of infrastructure projects. The reason why questionnaires are a popular method for collecting data is because of their suitability to deal with time constraints and a large sample size of people who are able to provide the intended data in relation to their views and experience (Naoum, 2007; Fink, 2009), which were also the primary considerations in this study.

A survey was regarded to be appropriate to answer the "what?" type of research questions (Fellows and Liu, 2015). In this study, the variables in the questionnaire are constructed based on the Indonesian government regulations' indicators of sustainable construction implementation, which creates sustainable infrastructure and eventually contributes to sustainable development. The indicators comprise four indicators of the selection of service providers (see Table III) and 16 indicators of implementation of sustainable construction (see Table IV). In addition, there are seven variables related to constraints to the implementation of sustainable construction, and they were gathered from the literature review (see Table V). The study was to test the perceived existence of the gap between the government regulations' indicators of sustainable construction and its practice in the execution of infrastructure projects as identified in this gap. Therefore, the main research question is defined as "what is the extent of the implementation of sustainable construction in the execution of infrastructure projects in Indonesia?" Three sub research questions are set to answer the main research question, as follows:

RQ1. What are the existing conditions for the implementation of service providers' selection based on sustainable procurement indicators?

This research question aims to evaluate whether the selection of service providers is made using sustainable principles indicators:

RQ2. What are the existing conditions for the implementation of sustainable construction indicators in infrastructure project execution?

This research question aims to evaluate whether the execution of infrastructure projects uses sustainable principles indicators:

RQ3. What are the barriers to sustainable construction implementation in infrastructure project execution?

This research question aims to identify the list of main barriers that can inhibit the implementation of sustainable principles in infrastructure project execution.

Questions in the survey were classified as "closed-ended"; they were restricted types of question which often require a short response from the respondent, such as to seek the opinion of contractors (Naoum, 2007). Since most of the questions sought opinions or a subjective measurement from the construction companies, the formats of such questions were based on an itemized rating scale and Likert scale. Sekaran and Bougie (2009) explained that the itemized rating scale provides flexibility in the number of scales the researcher wishes to use (e.g. 4, 5, 7), as needed, and the respondents choose the relevant number against each item in the questionnaire. In particular, the formats of such questions were based on an unbalanced itemized rating scale, where a neutral point is not provided (Sekaran and Bougie, 2009). Measuring the respondents' opinions for research questions (1) and (2), the unbalanced itemized rating scales consisted of 5 = often, 4 = sometimes, 3 = rarely, 2 = very rarely, 1 = never. Meanwhile, the research question (3) utilized a Likert scale of 5 = strongly agree, 4 = agree, 3 = neither agree/ disagree, 2 = disagree, 1 = strongly disagree, to collect the respondents' views and experiences relating to the barriers to sustainable construction implementation. The Likert scale is designed to examine how strongly subjects agree or disagree with statements on a 5-point scale (Sekaran and Bougie, 2009) or in order to rank responses in a 5-point format (Fellows and Liu, 2015).

Type of respondents

Determining the type of respondents for the study sample is very important so as to obtain the data needed to answer the research questions. Sample size for data collection in most research studies should be clearly considered according to time, cost and operational constraints to deal with studying an entire population. According to Fellows and Liu (2015), sampling should be a good representation of the population and enable the data collection and processing components of research to be carried out.

By using complex probability sampling designs, in particular stratified random sampling, this study employs representation of the population of local construction practitioners from among those with high-level and middle-level contractor qualifications. Stratified random sampling is a method employed to randomly choose a number of samples representing each stratum of a population (Fink, 2009); it has advantages of high generalizability of findings, and it is the most efficient among all probability designs (Sekaran and Bougie, 2009). The sample respondents are mostly undertaking building construction, road and bridge construction, water facilities construction and house and settlement construction, in the region of North Sulawesi Province, Indonesia. Based on the Ministry of Public Works and Housing public information, this province was allocated around 14.03 *tn* rupiahs for the cost of infrastructure construction or about 11.2 percent of the country's total infrastructure project value in 2018.

The construction companies are classified as B2 and B1, which is a high-level of contractors' qualification, due to their eligibility to construct projects with an unlimited value (B2 qualification) and up to 250 *bn* rupiahs for B1 qualification. M2 contractors are classified as middle-level and are eligible for projects up to 50 *bn* rupiahs. The respondents, therefore, can be considered to have experience of undertaking high-risk, high-tech and high-cost infrastructure projects. 200 questionnaire booklets were delivered to 40 companies, four B2 contractors, seven B1 contractors and 29 M2 contractors, with an average of five questionnaire booklets for each company grouping. All the companies returned the questionnaires, giving a company response rate of 55 percent (11 out of 20 companies of B2 and B1) for the high-level qualification and 58 percent (29 out of 50 companies of M2) for the middle-level qualification. A total of 158 useable questionnaires, equivalent to an individual response rate of 79 percent (158 out of 200 respondents), were completed by 30 project managers, 21 site managers, 20 quantity surveyors, 40 site supervisors, 23 civil engineers, 16 architects and eight environmental engineers. Sample size response rates of more than 50 percent are considered to have met the required sample sizes for the survey, as stated by Fellows and Liu (2015); a response rate of 25–35 percent is regarded adequate for questionnaire surveys in construction industry-related studies (Fellows and Liu, 2015). Table I shows the characteristics of the respondents in detail.

Method of data analysis

Data collected from the questionnaires were quantitative data, which were the output required from the survey. The data returned from 27 questions were then processed, analyzed and interpreted by using statistical techniques, to provide the information needed. Quantitative data analysis involves looking both at the general trends in the data and fitting statistical models to the data (Field, 2009). The Statistical Package for Social Sciences version 22 was utilized for the statistical analysis. Before conducting the data analyses, Cronbach's alpha was used to evaluate the internal consistency of the construction of the indicators, the results of which are shown in Table II. The closer Cronbach's alpha is equal to 1, the higher the internal consistency. An alpha over 0.80 is considered to be good, between 0.70 and 0.80 is acceptable, while below 0.70 is poor (Sekaran and Bougie, 2009). The Cronbach's alpha for all the main indicators was higher than 0.80. The internal

Characteristics of respondents	Responses per characteristic (n = 158)	Frequency (%)
Position		
Project managers	30	18.99
Site managers	21	13.29
Quantity surveyors	20	12.66
Site supervisors	40	25.32
Civil engineers	23	14.55
Architects	16	10.13
Environmental engineers	8	5.06
Work experience		
> 15 years	22	13.92
11–15 years	24	15.19
6–10 years	72	45.57
1–5 years	40	25.32
Organizations of respondents		
B2	16	10.13
B1	26	16.46
M2	116	73.41

Table I.
Profiles of respondents

Main indicators	Number of questions	Cronbach's alpha
(1) Selection of service providers	4	0.91
(2) Implementation of sustainable construction	16	0.94
(3) Constraints to the implementation of sustainable construction	7	0.82

Table II.
Reliability of internal consistency (n = 403)

Indicators	Mean	Standard deviation	Mean rank
(1) Procurement documents contain instructions for the use of efficient water and energy and environmentally friendly materials	3.34	1.24	4
(2) Procurement documents contain instructions to employ competent construction workers in their respective fields	3.92	1.34	2
(3) Procurement documents contain instructions to employ construction workers who must have certificates in their fields	3.99	1.31	1
(4) Procurement documents contain instructions regarding equal risk responsibility for the main parties who are involved in the construction project	3.78	1.32	3

Note(s): Level of implementation 5 = often (mean = 4.51–5.00), 4 = sometimes (mean = 3.51–4.50), 3 = rarely (mean = 2.51–3.50), 2 = very rarely (mean = 1.51–2.50), 1 = never (mean = < 1.50)

Table III.
Implementation of selection of service providers

consistency of the measures used in this study can, therefore, be considered to be acceptable for the measurement of sustainable construction indicators and constraints to the implementation.

Research results and discussion

The questionnaire survey highlighted indicators of sustainable construction implementation in Indonesian infrastructure projects and constraints as to its implementation. The issues

Indicators	Mean	Standard deviation	Mean rank
(1) Implement environmental management system in construction work	3.75	1.23	12
(2) Implement occupational health and safety management system in construction work	3.96	1.28	8
(3) Develop the concept of minimal construction waste produced during construction work	3.54	1.28	14
(4) Involve sub-contractors and suppliers who support sustainable principles	3.93	1.16	9
(5) The construction work target is set under the capacity of the contractor	4.44	0.99	1
(6) The construction work progress is in accordance with what is stated in the contract document	3.99	1.31	5
(7) Check and test the required material and temporary work results to see if they comply with the specified technical specifications	3.97	1.30	7
(8) Track project progress and always update it through a weekly checklist	3.84	1.34	11
(9) Review each construction work target to see if it meets the design document	4.03	1.23	3
(10) Test all of the project results to see if they comply with the requirements contained in the contract document	3.86	1.31	10
(11) Testing of all project results is carried out by competent third parties together with the owners and users	4.44	0.96	1
(12) Project owners and users maintain the construction work from the beginning	3.86	1.25	10
(13) Project owners and users acquire adequate training to utilize sustainable infrastructure before handover	3.66	1.07	13
(14) The contractor documents all the project processes that occur during the construction phase	4.24	1.26	2
(15) The contractor prepares a final report on construction execution, including a manual for sustainable infrastructure utilization and maintenance	4.02	1.35	4
(16) The contractor controls the construction execution through a checklist of integrated results between activities	3.98	1.23	6

Note(s): Level of implementation 5 = often (mean = 4.51–5.00), 4 = sometimes (mean = 3.51–4.50), 3 = rarely (mean = 2.51–3.50), 2 = very rarely (mean = 1.51–2.50), 1 = never (mean = < 1.50)

Table IV.
Implementation of sustainable construction

emphasized from the survey are divided and discussed according to the results from Table III to Table VI. Table III to Table V summarize a descriptive statistical analysis of the measurement of central tendency (mean) and the measurement of variation (standard deviation) to provide simple statistical models of the data of the evaluation on how the principles of sustainable construction exist in Indonesian construction circumstances, including the barriers to implementing them. The mean results were ranked, in particular, to depict the current status of sustainability-based procurement, the implementation of contractors' sustainability-based infrastructure project principles and the constraints to the implementation of sustainable construction. Standard deviation measures how well the mean represents the data, where small standard deviations indicate that the mean is a good fit with the data (Field, 2009) or spread of data is close to the mean value.

Table VI summarizes further analysis of the ANOVA test to examine whether there were differences in the implementation of sustainable construction principles and the existing barriers to implementing the principles among the respondents from the three groups of contractor qualifications. ANOVA produces F-ratio (F), which tells us that the means of

Indicators	Mean	Standard deviation	Mean rank
(1) Additional project development costs	3.97	0.82	1
(2) Lack of resources that support technological change	3.94	0.73	2
(3) Lack of partners' understanding of the benefits of sustainable development	3.52	0.93	3
(4) Lack of green technology support and technical guidelines for implementing sustainable construction	3.52	0.95	3
(5) Lack of coordination of resources for sustainable construction development	3.47	0.92	4
(6) Lack of skilled labor for sustainable construction development	3.43	1.01	5
(7) Contractor weaknesses on strategy, leadership and corporate culture that support sustainable construction	3.09	1.12	6

Note(s): Statement of constraints 5 = strongly agree (mean = 4.51–5.00), 4 = agree (mean = 3.51–4.50), 3 = neither agree/disagree (mean = 2.51–3.50), 2 = disagree (mean = 1.51–2.50), 1 = strongly disagree (mean = < 1.50)

Table V. Constraints of sustainable construction implementation

Variable		Group	Mean	*F*	Sig
1	Procurement documents contain instructions to employ competent construction workers in their respective fields	*B2*	*4.94*	*5.839*	*0.004*
		B1	4.00		
		M2	3.76		
2	Construction work in the field implements an Environmental Management System	B2	3.63	*7.691*	*0.001*
		B1	*4.58*		
		M2	3.58		
3	Work in the field applies the concept of development with very little construction waste production	B2	3.06	*3.599*	*0.030*
		B1	*4.08*		
		M2	3.49		
4	Work in the field involves sub-contractors, suppliers, labor and equipment that support sustainable principles	B2	*4.94*	*23.450*	*0.000*
		B1	4.81		
		M2	3.59		
5	The administration of the construction contract is in accordance with what is stated in the applicable contract document	*B2*	*4.75*	*3.332*	*0.038*
		B1	4.08		
		M2	3.87		
6	Check and test the required material and temporary work results to see if it is in accordance with the specified technical specifications	*B2*	*4.81*	*3.907*	*0.022*
		B1	3.85		
		M2	3.88		
7	Track project progress and always update it through a weekly checklist	*B2*	*4.69*	*3.844*	*0.023*
		B1	3.62		
		M2	3.78		
8	Review each target set in the design document	*B2*	*4.50*	*3.397*	*0.036*
		B1	3.54		
		M2	4.07		
9	Testing of all results of the construction implementation is carried out by competent third parties, together with the owners and users of the project results	*B2*	*5.00*	*12.825*	*0.000*
		B1	3.69		
		M2	4.53		
10	Availability of resources that support technological change	B2	3.50	*4.626*	*0.011*
		B1	*4.19*		
		M2	3.95		
11	Lack of green technology support and technical guidelines for implementing sustainable construction	B2	3.25	*5.99*	*0.003*
		B1	*4.08*		
		M2	3.43		

Table VI. ANOVA test results for sustainable construction implementation the three group samples are not equal (Field, 2009), as indicated by the Sig being less than 0.05, meaning there is a statistically significant difference (Allen and Bennet, 2010) between the sustainable construction implementation of at least two of the contractor groups. The types of method of analysis that have generated the results of the study serve as an overview of the existing sustainable construction practices in Indonesia, as well as being a good starting point for future studies in this area.

Table III provides the overall results of analysis of mean, standard deviation and mean rank regarding the implementation of sustainable principles in the selection of construction service providers. The mean rank was used to indicate the most commonly implemented sustainable procurement indicators. The sample contractors rarely experience the procurement documents that contain instructions to use water and energy efficiently and environmentally friendly materials (mean = 3.34). They also stated that the need to have equal risk responsibility among the main construction project parties (mean = 3.78) and to employ competent construction workers (mean = 3.92) who are certified in their field (mean = 3.99), as required in the procurement documents, frequently do not exist. Based on the results in Table VI, as high-level qualification contractors, B2 contractors are more concerned with the availability of competent construction workers in their respective fields, in order to meet the requirements of the procurement documents (mean = 4.94), compared to B1 and M2 contractors. These findings reveal that government regulations on the availability of sustainable construction-based procurement documents have not yet been consistently implemented during the selection of service providers. Obviously, it is necessary for the government to pay attention to the procurement process since it determines the main construction service providers who have professional ability and commitment to pursue Indonesian government targets for creating sustainable infrastructure, which will contribute to sustainable development.

In practice, sustainable procurement in government projects is understood as a process whereby the government, in the context of meeting the needs for construction works and services, assesses not only the project cost and capability aspects of service providers but also assesses social and economic aspects and the minimum damage to the environment (Da Silva *et al.*, 2018). According to Hasselbalch *et al.* (2014), the implementation of sustainable procurement still faces obstacles, partly due to the lack of training on the sustainable procurement process and the lack of available policies governing sustainable procurement, as well as the low entrepreneurial capacity and risk-taking of contractors and suppliers (Prier *et al.*, 2016). Meanwhile, according to Sanchez *et al.* (2014), the government's policy to provide incentives for contractors and suppliers in implementing sustainable procurement, as well as policy of a low tax rate for the sustainable construction material (Agbesi *et al.*, 2018), would maximize the practice of sustainable procurement for construction projects. Consequently, the Indonesian government should move on from project life cycle-based procurement process to a product life cycle procurement process. A project life cycle-based procurement process ensures project planning and execution, up to project handover, are based on project specification and other client and user requirements. However, the product life cycle procurement process ensures project planning, design, execution, operation and maintenance, up to project demolition, in generating sustainable construction product. These project phases will then be considered as a sustainable project life cycle.

Previous research has already addressed the positive role of sustainable construction on environmental safety and health (Koranda *et al.*, 2012; Abd Jamil and Fathi, 2016; Balasubramanian and Shukla, 2017); however, generally, Indonesian contractors cannot meet the fundamental concepts of reducing the use of energy and water, preventing pollution and applying waste minimization. Since the government itself has not consistently required contractors to focus attention on environmental health and safety as a result of construction work, there will be slow movement in terms of introducing sustainable construction principles at the initial stage of project procurement. Inadequate government policies or support are also one of the most significant challenges of sustainable construction practices in developing countries (Aghimien *et al.*, 2019). Sustainable construction is, instead, a new concept within the Indonesian context; hence, the role of government is crucial not only in terms of issuing the regulations but also monitoring the implementation of the regulations up to the working units (i.e. the sectors on building construction, road and bridge construction, water facilities construction and house and settlement construction), which are responsible for conducting the execution of infrastructure projects from project initiation, including procurement activity, to project maintenance. A number of studies (Zhou *et al.*, 2013; Sfakianaki, 2015; Upstill-Goddard *et al.*, 2016; Shurrab *et al.*, 2019) have highlighted the importance of government in actively encouraging all parties in charge of targeting a sustainable construction agenda.

In the existing research results, the contractors have noticed the importance of using competent workers, whereby this makes it easier for contractors to enhance their knowledge in the field of sustainable construction. Sfakianaki (2015) stated that training and investment in resource-efficient building methods and practices are strategic to developing an awareness of sustainable principles in construction. This awareness supports the positive contribution of project management knowledge and skills to sustainable construction, since project management is an essential prerequisite for designing, delivering and managing in this environment (Agyekum-Mensah *et al.*, 2012). Karunasena *et al.* (2016) found that it is not enough for the construction experts to simply have good knowledge without being able to practice sustainable construction satisfactorily. Moreover, commitment to and knowledge of sustainable concepts are transferred and adopted in terms of new ways of working, thinking and learning to boost stakeholders' performance and motivation (Trufil and Hunter, 2006; Abdullah *et al.*, 2009; Tan *et al.*, 2011; Sfakianaki, 2015; Abd Jamil and Fathi, 2016; Schröpfer *et al.*, 2017). Human resource capacity is the key to the success of infrastructure since the construction workforce involved in the planning, implementation and supervision phases must be competent and certified.

Developing and implementing the concept of sustainability in a construction project should involve equal risk responsibility, such as investment cost (Karunasena *et al.*, 2016), proper enlightening and understanding of construction stakeholders in terms of sustainable construction great values (Aghimien *et al.*, 2019) and social risks (Goel, 2019). For this reason, joint responsibility of the government, construction service actors and the community is needed in supporting the implementation of sustainable construction practices in Indonesia. Considering the socio-cultural conditions of Indonesia, the social risks must not be ignored; however, they are acceptable as opportunities in developing sustainability actions for infrastructure projects. The most concrete example of social risks is the issue of land acquisition in road infrastructure projects. According to Goel (2019), construction professionals should know how to mitigate the social risks as they are becoming common in built environment projects; therefore, policies and regulations on sustainability actions should also accommodate community involvement and roles.

Table IV describes the mean rank and standard deviation of sustainable construction indicators in Indonesian infrastructure project execution. In general, based on the sample respondents' perceptions, most of the indicators are well-understood by the respondents. However, implementation is not yet wholly satisfactory, as shown by the mean ranks of 12, 13 and 14, which indicate that their acceptance of the indicators is still inconsistent. The critical issues with regard to the lack of sustainable principles during infrastructure project execution are minimal construction waste production (mean = 3.54), project owners and users acquiring adequate training to utilize sustainable infrastructure before the handover (mean = 3.66) and the implementation of Environmental Management System (EMS) in construction work (mean = 3.75).

To recognize where the differences exist between the three contractor qualifications during construction execution, Table VI shows that *B*2 contractors are likely to put more emphasis on several regulations regarding the implementation of sustainable principles in infrastructure project execution than B1 and M2 contractors. Those with this highest qualification are likely to be trying to choose sub-contractors who can support sustainable construction works (mean 4.94). They admit that the administration of the construction contract should follow what is stated in the applicable contract document (mean = 4.75). In terms of project control, they implement steps such as checking and testing the required material and temporary work results to see if this is in accordance with the specified technical specifications (mean = 4.81), tracking project progress and always updating it through a weekly checklist (mean = 4.69), reviewing each target set in the design document (mean = 4.50) and testing of all results of the construction implementation to see if it is carried out by competent third parties, together with the owners and users of the project results (mean = 5.00). Within the national competition area, the B2 contractors have competed with those with medium- and small-scale qualifications, leading them to considerably implement the sustainable construction regulations as consistently as possible. During construction execution, issues of an environmentally friendly construction project are dominant. This study reveals that the other highest qualification contractors (B1) are likely to try to implement an environmental management system during the construction work (mean = 4.58) and pay more attention to minimizing construction waste production (mean = 4.08). Due to tight competition, B1 contractors see the issue of construction waste management as a strategic tool to improve their performance.

Previous research has already addressed how waste management strategy and practice (Tan *et al.*, 2011; Yates, 2013; Djokoto *et al.*, 2014) are needed by the construction organization to implement minimal construction waste production. Yates (2013) reviewed the main types of sustainable materials that could be recycled and reused during the construction design stage and examined sustainable strategies associated with techniques to reduce the amount of waste being generated during construction, processes to recycle waste at the end of construction and to sell or reuse material by-products. These insights surely involve technological readiness; however, it requires policy to govern waste minimization strategies for Indonesian construction processes. Moreover, current studies in green construction practices (Balasubramanian and Shukla, 2017; Murphy and Nahod, 2017; Shurrab *et al.*, 2019) have revealed that, by governing and facilitating environmental/EMS programs, such as green supply chain management, EMS training and auditing, the adverse environmental impacts on infrastructure projects can be curtailed for improved sustainable construction performance. Within the Indonesian context, knowledge and training about the application of EMS should be focused much more on construction waste, together with how to maintain environmental preservation in the area of infrastructure operations, which is one of the findings of this study. In addition, focusing on training programs for project owners and users to utilize sustainable infrastructure before product handover can maintain the performance and utilization of the products maximally. In order to improve the sustainability performance of infrastructure products, as stated by Sfakianaki (2015), sustainable construction should have a low negative impact on the environment over its entire lifetime while optimizing its economic viability and still maintaining aesthetics, comfort and safety. In principle, for Indonesian construction to continuously be able to implement sustainable performance for infrastructure projects, investment in training, EMS programs and waste management technologies, together with the seriousness of the government and related parties to respond to global issues in creating sustainable development, are imperative throughout the sustainable infrastructure project life cycle.

Table V shows constraints in the implementation of sustainable construction. The most common constraints are due to increased project development costs (mean = 3.97) and lack of resources that support technological change (mean = 3.94). These findings support the significant difficulties impeding the execution of sustainability-based infrastructure projects, as stated by Opoku and Ahmed (2014), Karunasena *et al.* (2016) and Aigbavboa *et al.* (2017). Most contractors also agreed that sustainable construction implementation faces barriers due to a lack of partners' understanding of the benefits of sustainable development (mean = 3.52) and lack of green technology support and technical guidelines for implementing sustainable construction (mean = 3.52). Similarly, the most critical barrier to the adoption and promotion of green building practices in Pakistan is lack of awareness about the benefits of green building practices (Azeem *et al.*, 2017).

Currently, medium contractor qualifications dominate the infrastructure project market, and they strongly take into account what the project cost is used for and the designation and benefits of the project budget allocation (Upstill-Goddard *et al.*, 2016); therefore, inevitably, the respondents have found it difficult to provide excessive project investment, such as for green construction technology. Although the high-level contractors have realized the importance of green technology, they also need the same understanding from their partners, such as the middle-level contractors and other sub-contractors and suppliers; this condition needs comprehensive communication and collaboration among project members on knowledge sharing theory and promoting green technology to support sustainability-based construction development. According to Abrahams (2017), the understanding of sustainable construction that supports sustainable development should be more extensive within the construction industry to ensure effective collaboration across the sector as a whole, hence, to improve the efficiency of design, procurement and construction processes. Nevertheless, most developing countries still practice unsustainable design and construction processes, which causes constant degradation of the environment (Abd Jamil and Fathi, 2016; Aghimien *et al.*, 2019).

Among the three groups of respondents (see Table VI), B1 contractors are the most concerned with the lack of resources that support technological change (mean = 4.19) and the lack of green technology support as well as the availability of technical guidelines for implementing sustainable construction (mean = 4.08). They have realized the need for advanced and green technology, although it is still an obstacle. They should be prepared to be involved in this new paradigm of sustainable development, which can be achieved through the provision of sustainable construction. Ervianto (2015) built a green construction model that involves contractor, community and environment in an effort to achieve sustainable development in Indonesia.

In fact, several constraints might hinder the ability to implement sustainable construction implementation in the execution of infrastructure projects. There should be drivers or motivating factors for the government, as project owner, and the companies, as construction services providers of infrastructure projects, to implement sustainable principles. Acceptance and self-responsibility of the on-site personnel is vital for the successful implementation of novel practice (Waidyasekara *et al.*, 2017), such as sustainable construction. This kind of self-awareness would help overcome the barriers in the process of implementing sustainable construction, especially in terms of coping with cultural barriers (Froner, 2017), lack of green technology and techniques (Balasubramanian and Shukla, 2017), quality of specification, leadership and responsibility, client's preference (Aghimien *et al.*, 2019), benchmarking systems (Sarhan and Fox, 2013; Samari *et al.*, 2013; Djokoto *et al.*, 2014) and safety, efficiency, productivity and waste minimization (Abd Jamil and Fathi, 2016).

Conclusion and recommendations

This study evaluates the means of implementing sustainable principles in the execution of infrastructure projects in Indonesia based on the perceptions of main construction service providers and their partners, by identifying gaps between the government regulations' indicators of sustainable construction and its practices, including constraints to the implementation. Barriers always exist that hinder the implementation of new concepts, such as sustainable construction. The study has indicated the need for more practice of sustainable principles in Indonesian infrastructure projects through the gap analyzed from the results.

Firstly, this study reveals indicators of sustainable procurement which are still obstacles for both the government and contractors to implement. Through a questionnaire survey, the efficient use of water and energy and environmentally friendly materials were perceived as unusual principles to be included in the procurement documents. It is recommended that the concern of local government to successfully consistently implement sustainable principle-based construction be started from the procurement phase, by establishing criteria in the selection of service providers that emphasize green construction throughout the product life cycle procurement processes. This suggests that the construction service providers to have proven documentation showing they are qualified to conduct green construction procurement and processes. This study also highlights the importance of human resource capacity to enhance their awareness, knowledge and skills in the planning, implementation and supervision phases of infrastructure projects. Practicing sustainable procurement should involve equal risk responsibility, including social risks as opportunities in developing sustainability actions for infrastructure projects.

Moreover, this paper is one of the first efforts to reveal that environmental practices are not easy to implement for Indonesian contractors during construction execution. The concept, such as minimal construction waste production as a part of the possession of the EMS, has not been consistently fully implemented. A series of challenges that follow sustainable construction practices in infrastructure projects execution has been evaluated from this study. Additional project development costs, lack of technical support and construction stakeholders' understanding of the benefits of implementing sustainable construction principles were perceived as significant barriers in constructing infrastructure projects, all of which lead to a rare opportunity for the project owners and users to be trained to utilize sustainable infrastructure before project handover. Therefore, knowledge transfer about sustainable principles among all project participants, supported by well-trained and competent contractors regarding environmental, social and economic viewpoints would support the execution of infrastructure projects from the planning phase to project handover.

Finally, the study contributions can be viewed as a contribution to the body of knowledge, to practical implications and to social implications. The findings of this study contribute to the body of knowledge as they show that the principles of sustainable construction applied to infrastructure projects should start from the procurement phase and continue to the execution phase. The execution of sustainable infrastructure must take into account principles of safety, balance and the harmony of infrastructure and the environment, both in the present and in the future, and these are well-documented in the project reports. Its value also lies in the evaluation of the barriers to sustainable construction implementation in infrastructure project execution in this country, wherein this study will contribute to further studies on the constraints to sustainable construction implementation in other developing countries. The perception and acceptance of what is sustainable construction and how it works successfully in infrastructure project execution should also be further studied to evaluate the extent to which sustainable construction principles are continuously implemented.

In terms of practical implications, the findings suggest that construction industry practitioners, policy makers and other related stakeholders should take note of the current status of sustainable principles on the procurements documents and in the execution of infrastructure projects including the challenges to sustainable construction. Policy makers may develop technical instructions that contain technical requirements that enable the practitioners to undertake sustainable infrastructure projects, as well as assessment criteria to ensure the requirements of sustainable procurement can be met. Infrastructure development as a top government priority is a logical and strategic decision which would increase Indonesia's competitiveness as well as remedying its backwardness. This study suggests that the involvement of policy makers and main construction parties should lead them to become innovative pioneers to equalize their objectives, scope and targets for the implementation of sustainable infrastructure in the realization of sustainable development in Indonesia.

In the context of social implications, these findings pave the way for whole social inclusion in the process of construction infrastructure projects, covering promoting citizens' responsibilities to looking after and continuously monitoring the performance of the facilities and participating in training and development to continuously monitor the performance of the facilities. A lesson-learned with regard to construction companies with sustainable development goals is that there is a need to improve and strengthen cooperation among those with high-level and middle-level qualifications and their sub-contractors/ suppliers as well as civil society to create a sustainable infrastructure that fulfills the requirements of sustainable development.

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