Jurnal Aplikasi Teknik Sipil
Volume 20, Nomor 1, Februari 2022

Journal homepage: http://iptek.its.ac.id/index.php/jats

Assessing Highrise Building Construction in Semarang Using Green Construction Site Index (GCSI)

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Info Artikel
Diajukan 05 November 2021
Diperbaiki 28 Desember 2021
Disetujui 02 Januari 2022

Keywords: Waste, Green Construction, Environment, Construction Site

Kata kunci: Limbah, Konstruksi Hijau, Lingkungan, Lokasi Proyek

Abstract

The advancement of the construction industry in Indonesia has been considerably contributing to the upgrade of the social and economic. The advancement may be ensnared within the mishandle of environment maintainability. The objective of the study was to analyze the performance of the ongoing construction projects implementing the green construction concept. The tool applied was the Green Construction Site Index (GCSI) to assess five construction projects categorizing into three groups or specifications (uncommercialized, non-residential building; commercial, residential building; and commercial, non-residential building). The index of efficiency, productivity, and awareness upon three types of buildings was 4.06, 4.49, and 4.31 respectively. Meanwhile, the overall index obtained by the construction project type I, II, and III was 4.07, 4.33, and 4.35 respectively. The tool might be considered an opportunity to contractors, although further investigation on its application in other types of buildings is needed.

Abstrak

Perkembangan industri konstruksi di Indonesia sangat memberikan kontribusi terhadap peningkatan aspek sosial dan ekonomi. Sistem pengelolaan lingkungan yang tidak optimal akan menjadi persoalan dalam perkembangan industri konstruksi. Penelitian bertujuan memberikan analisis penerapan konstruksi berkelanjutan dalam pelaksanaan konstruksi. Pedoman atau alat ukur yang digunakan adalah *Green Construction Site Index* (GCSI) untuk menilai lima proyek konstruksi yang dikelompokkan ke dalam tiga kategori (bangunan tidak komersial, bukan hunian; komersial, hunian; komersial, bukan hunian). Indeks efisiensi, produktivitas, dan kesadaran yang diperoleh ketiga tipe bangunan masing-masing adalah 4,06, 4,49, dan 4,31. Sementara itu, keseluruhan indeks yang diperoleh proyek konstruksi tipe I, II, dan III secara berurutan adalah sebesar 4,07, 4,33, dan 4,35. *Green Construction Site Index* (GCSI) dapat digunakan sebagai sarana evaluasi bagi pelaksana konstruksi, serta diperlukan penelitian lanjutan tentang penerapannya di jenis bangunan lain.

1. Introduction

An exceedingly rapid infrastructure development accelerates construction projects to increase [1], promotes, and accelerates economic development [2]. However, substantial waste and power loss [3] lead the enterprises to be the factor causing the surrounding contamination [4] and the impact from the construction on the environment has caused ecosystems, health, and wellbeing to be affected significantly [5]. High order infrastructure projects, mainly commercials, and residences are, the principal donors to waste generation [6].

Construction and demolition (C&D) significantly contribute quantities of all solid waste [7]; for example, industrial construction in the USA produces C&D waste of more than 100 million tons per year [8], among which 29% is from the buildings [9]; meanwhile, UK shares landfill volume by more than 50% from which 70 million tons are discarded each year [10]. Construction-related solid waste is nearly 23% in Hong Kong. The facts suggest the importance of being aware and careful to manage waste left by the construction process [11]. In addition, according to Ofori and Ekanayake [12] modification in design and residual particles cause waste generation during development, such as construction class, project size, design, and others [13].

Meanwhile, regarding waste minimization, prefabrication installation systems, such as precast concrete components and steel formwork systems, confirmed a significant decrease in the number of concrete wastes compared to regular cast-in-situ using timber formwork [14]. Meanwhile, the absence of employing construction materials, based on an environmentally friendly, causes sustainable failure in maintaining the construction process in Indonesia [15]. In addition, waste management concern about disposal is very limited [16].

To solve waste generation-related problems is green construction [17] in combination with implementing waste management [18] besides reducing, reusing, and recycling principles, production techniques, and awareness of the negative impacts [19]. As a result, assessing the achievement of production outlines related to environmental concerns should be estimated quantitatively [20].

Thus, the objective of the research was to analyze the effectiveness of the Green Construction Site Index in assessing the performance of three building construction types; uncommercialized non-residential construction, commercial residential construction, and commercial non-residential building. The formulation is expected to contribute concept to both parties so that construction industry practices will always regard the rules and regulations as the government will do the same.

2. Materials and Methods

The primary data analyzed were collected from 5 buildings categorized into type I (uncommercialized non-residential construction); type II (commercialized residential construction); and type III (commercialized non-residential construction). Data collection which used questionnaire survey, was conducted during construction period. Each construction was given one questionnaire, which in filling it involves several parties, from planning consultant and main contractor as a validation of the data provided. The tool used to assess the performance of the green construction concept applied was Green Construction Site Index [14] that emphasizes three aspects: efficiency, productivity, and awareness. Those three aspects include 133 factors which were compiled from green construction concept references and were validated by respondents [21]. The assessment is carried out by categorizing the results of the implementation of green building into four categories. If it reaches the number (index = 4.0-5.0), it is included in the excellent category, which means that it meets at least 80% of the 133 factors. Meanwhile, the good category (index = 3.0-3.9) meets at least 60% factor have been realized, then the third category is need improvement (index = 2.0-2.9) only reaches 40% of the total and the last one is only 20% of all indicators include in lack of commitment category (index = 1.0-1.9).

3. Result and Discussion

A. Efficiency

The two factors of efficiency, waste minimization and sustainable green construction, were scored, and the efficiency index exhibited the level of realization of an ongoing project can be seen in ***Table 1****.*

Table 1*. Index of Efficiency of 5 Project*

	Factor	Construction Project					Average
		Type I	Type II		Type III		
		1	2	3	4	5	
1	Waste Minimization	4.50	4.66	4.23	3.90	3.90	4.24
2	Sustainable Green Construction	3.09	3.39	4.66	4.43	3.79	3.87
	Average	3.80	4.03	4.45	4.17	3.85	4.06

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

Table 1 *exhibits that the average score of the efficiency of five projects is 4.06, compiled from waste minimization and sustainable green construction (4.24 and 3.87, respectively). The projects that deserved good category were project #1 type I, project #4 and project #5 type III have an index of 3.80 and 3.85. Even though it is in a good category, it shows the lowest value than the others. This number was likely caused by the implementation of sustainable green construction almost failing to meet the expectation (index=3.09). Meanwhile, projects #2, #3 type II, and #4 type III were categorized as excellent. Meanwhile, the highest index (4.45) shown in project #3 included the excellence category.*

Table 2 *exhibits the commitment level demonstrated by all employees involved in the project. The commitment index performed by field workers (4.07) is lower than that of policy makers at the head office management (4.47) but higher than that of the site managers (3.49). The data suggested that the efficiency had been well adopted and implemented by policy makers (policial level), although their supervisors (procedural level) were likely to be given a relative lack of attention notably the index of maximization reuse of component building was 2.83. It means all projects need to find alternative ways to improve. In measuring the degree of understanding gap between management and field operators' level, a tool was needed in controlling the chain of command.*

For that reason, considering its effectiveness, GCSI was proposed to be the applicable one to provide a control mechanism that ties up the management and the field level.

B. Productivity

Productivity, the second parameter of GCSI was an equally important parameter as others did because productivity reflected the ability of efficiency and awareness to perform following the criterion, among which was the management of material handling. This factor consisted of five indicators.

***Table 3** reveals that the parameter of material handling management conducted by 5 projects satisfies the criterion; the average index of the five projects is 4.49 (excellence). The performance of all the projects has met the criterion. The index should be maintained by increasing some factors that include in the good category. The material wastage assessment parameter in project #1 and project #3 indicates the lowest index than the other. Meanwhile, on the controlling of reinforcement bar (rebar) waste parameter almost all projects include excellence category, except the index of project #2 was 3.0 (good category). Overall, of the assessed project that has the highest index was project #4 (4.79). When the findings were crossed reference to the degree of commitment the five projects were carried out, the following **table 4** summarizes.*

***Table 2**. The Degree of Commitment of Five Projects on The Parameter of Efficiency*

Parameter	Commitment					
	Policy	Index	Procedure	Index	Practice	Index
Efficiency	The Use of Pre-Fabrication Construction Elements	3.67	The Application of Environmentally Friendly Product	3.32	The Availability of Bins in Construction Site	4.65
	The Capability of Subcontractor in Constructing Waste Treatment	4.87	The Maximization Reuse of Component Building	2.83	The Implementation of Construction Waste Arrangement	4.73
	The Comprehensiveness of Contract Documents	5.0	The Documentation of Reusing and Recycling Construction Waste	4.32	The Utilization of Recycled Material	2.83
	The Comprehensiveness of Construction Design and Planning	4.33				
	Index	4.47	Index	3.49	Index	4.07

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

***Table 3**. Material Handling Management Indicators*

	Indicator	Construction Project					Total	Index
		Type I	Type II		Type III			
		1	2	3	4	5		
1.	The Establishment of Material Application Procedures on Construction Site	4.4	4.0	5.0	4.0	5.0	22.39	4.48
2.	The Material Selection and Utilization	4.2	5.0	5.0	5.0	4.0	23.22	4.64
3.	The Material Wastage Assessment	3.6	5.0	3.0	5.0	4.0	20.64	4.13
4.	The Controlling of Reinforcement Bar (Rebar) Waste	4.6	3.0	5.0	5.0	5.0	22.61	4.52
5.	The Controlling of Concrete Waste	4.8	5.0	4.3	5.0	4.3	23.29	4.66
	Total	21.7	22.0	22.3	24.0	22.3	112.15	4.49
	Index	4.34	4.39	4.45	4.79	4.45		

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

***Table 4**. The Degree of Commitment of Five Project Upon the Parameter of Productivity*

Parameter	*Commitment*					
	Policy	*Index*	*Procedure*	*Index*	*Practice*	*Index*
Productivity	*The Establishment of Material Application Procedures on Construction Site*	*4.48*	*The Material Selection and Utilization*	*2.83*	*The Material Wastage assessment*	*4.13*
			The Controlling of Reinforcement Bar (Rebar) Waste	*4,52*		
			The Controlling of Concrete Waste	*4.66*		
	Index	*4.48*	*Index*	*4.00*	*Index*	*4.13*

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

*In **Table 4**, the commitment level of the personnel in the organization to the parameter of productivity was not consistent. The problem was taken place at the middle level of the organization (procedural level). The existing problem related to the prosedure level, on the material selection and utilization parameter with index 2.83 (need improvement).*

C. Awareness

The purpose of a project based on the sustainable green construction concept to achieve had to underlie policy, procedure, and practice. Sustainable construction meant that cities and buildings responded to the emotional and psychological needs of people by providing stimulating environments, raising awareness of important values, inspiring the human spirit, and bonding societies, communities, and neighborhoods. In this case, awareness was defined as the responsiveness of any level in a project structure to develop such competence that relate to environmental performance on construction site and understanding of construction waste by give some training also rules for all employees.

***Table 5**. The Index of Awareness of 5 Projects*

	Factor	*Construction Project*					*Average*
		Type I	*Type II*		*Type III*		
		1	*2*	*3*	*4*	*5*	
1	*Environmental Performance on Construction Site*	*4.10*	*3.59*	*4.39*	*4.39*	*3.83*	*4.06*
2	*Understanding of Construction Waste*	*4.09*	*5.00*	*4.30*	*5.00*	*4.43*	*4.56*
	Average	*4.09*	*4.29*	*4.35*	*4.69*	*4.13*	*4.31*

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

*As shown in **table 5**, the average index score of awareness among the five projects is 4.31, consisting of Environmental Performance on Construction Site (4.06) and the Understanding of Construction Waste (4.56). All projects belonged to the Excellence Category. Even though, a consideration emphasized an aspect of sustainable green construction concepts such as construction waste generation and natural resource depletion were significant factors to be concerned. Globally, estimated waste disposal (10 to 30 %) is from construction and demolition activities [21]. Yet, although the tremendous waste is from construction ones, the policy of the Malaysian contractors does not prioritize the importance of sustainable resources and waste management [6].*

Globally, an estimation of approximately 10 to 30 percent of wastes disposed of in landfills originates from construction and demolition activities [21]. In Malaysia, construction waste is the highest waste stream, yet despite some government policy initiatives to address this issue, sustainable resource, and waste management on site remains a low priority for the majority of the contractors [6]. In addition,

*Rogoff and Williams [22] proposed a waste management strategy that covered records of waste documentation, understanding the waste concept, and identifying tools to measure the waste. T**able 6** evaluates the parameter of awareness and commitment.*

***Table 6**. Degree of Commitment of Five Project Upon The Parameter of Awareness*

Parameter	Commitment					
	Policy		Procedure		Practice	
Awareness	The Establishment of Reward & Punishment based on Environmental Requirements	2.93	The Promotion of Environmentally Responsible Behavior	4.98	The Water Pollution Control	2.90
	The Procedural Operation of the Construction Equipment	4.70	The Awareness of Construction Equipment Implication to Environment	4.79	The Training of Construction Waste Reduction	4.67
	The Construction of Waste Management and Environmental Site Planning	4.04	The Anticipation to Construction Waste Generation	4.80	The Air Pollution Control	4.53
					The Noise Pollution Control	4.77
	Index	3.89	Index	4.86	Index	4.22

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

***Table 7**. Performance Of 5 Projects Assessed Using GCSI*

	Parameter	Construction Project					Average
		Type I	Type II		Type III		
		1	2	3	4	5	
1.	Efficiency	3.80	4.03	4.45	4.16	3.85	4.06
2.	Productivity	4.34	4.39	4.45	4.79	4.45	4.49
3.	Awareness	4.09	4.29	4.35	4.69	4.13	4.31
	Average	4.07	4.24	4.41	4.55	4.14	4.40
	Average	4.07	4.33		4.35		4.31

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

***Table 6** exhibits that the commitment of all levels of the organizational structure meets the criterion. The average index of each level of awareness is 3.89 (good category), 4.86 (excellence category), and 4.22 (excellent category). the problems dealing with the performance of the field workers was that their commitment to implement water pollution control was below the expectation (index = 2.90). The data could be interpreted that there was still a problem in understanding the duty between the site manager and the field workers. For example, the establishment of reward & punishment based on environmental requirements (index= 2.93), which was policy-level responsibility, was well adopted by the middle management by promoting of environmentally responsible behavior (index = 4.98), but the site manager's instruction was not well implemented by the field workers as shown by its index of 2.90 for water pollution control.*

Previously, Firmawan [23] proposed the importance of measuring the consequence effects of ongoing construction to identify and comprehend the reduction methods. To achieve this, labor should be well-performed in carrying out the process. Poon [24], supported by good communication or relationship between workers and management, and therefore, limiting and irrelevant fashions determine the achievement of the goals [25]. Therefore, the performance of a project depends on interrelated factors, such as labor, site management, method, and others [26].

D. Green Construction Index

Quantifying an assessment of an ongoing project by scoring its completion on the spot using GCSI, represented by the index, illustrated the intention of the management to fulfill the requirements of the sustainable green construction concept. The GCSI functioned to validate and examined every indicator related to obtaining the sustainable green construction concept. ***Table 7*** *show the achievement of the 5 projects to assess how this tool effectively works. The average index of five projects assessed was 4.31 (excellence category); however, among the three parameters, the efficiency of the 5 projects needed to be improved as the GCSI they reached was only 4.06, while the index of productivity was 4.49 and the index of awareness was 4.31. Even though three parameters categorized excellence category, factors, indicators, and variables were needed to be improved to meet the criterion of maximum score index of excellence category. The data suggested that all projects, individually, deserved to be in the good and excellence category. In the perspective of categorizing, the average index of the type I group was 4.07 (the lowest) compared to the type II group (4.33), and type III group (4.35). The problem is efficiency that its cause can be traced to the efficiency index. In the factor sustainable green construction, the average index of all projects was 3.87 (contained* ***in tabel 1****) which means need upgrades in construction waste arrangement also reuse-recycle waste construction.* ***Table 7*** *also exhibited that the average score earned was not influenced by the types of construction projects a contractor was working on. The average score of the GCSI of the uncommercial non-residential building (type I) was 4.07; while the average score of the GCSI of commercial, residential building (type II) was 4.33, and the average score of the GCSI of the commercial non-residential building (type III) was 4.35.*

The contractors' performance based on the GCSI upon the types of building that belong to the good category suggested that the type of building a project was carried out did not influence the commitment of the contractor in establishing the sustainable green construction concept. ***Table 7*** *also displays that the index of every project observed belongs to a good category, the lowest score was 4.07, and the highest score was 4.35.*

Project performance based on the GCSI index of building types in good categories suggests that the type of building the project is running does not affect the project's commitment to establishing the concept of sustainable green building. The difference between the five projects in terms of commitment to the observed variables was the understanding of all staff involved and their commitment to avoiding the negative environmental impact of construction. To summarize, ***table 8*** *illustrates the relationship between the organizational level and the parameter of the GCSI.*

Table 8*. The Commitment Index of Personnel Within the Organizational Structure on The GCSI Parameters*

Parameter	*Commitment Index*			*Average*
	Policy	*Procedure*	*Practice*	
1. Efficiency	*4.47*	*3.49*	*4.07*	*4.01*
2. Productivity	*4.48*	*4.00*	*4.13*	*4.20*
3. Awareness	*3.89*	*4.86*	*4.22*	*4.32*
Average	*4.28*	*4.12*	*4.14*	*4.18*

Note: 4.0 – 5.0 = excellence; 3.0 – 3.9 = good; 2.0 – 2.9 = need improvement; 1.0 – 1.9 = lack of commitment

Table 8 *shows problems that personnel encountered to meet the requirement of the Green Construction Site Index. The most modest one was the parameter of efficiency. At the site, workers were not respectless the management procedure (index= 3.49). Meanwhile, middle management encountered problems related to productivity (index= 4.00). Overall, the commitment of the field workers to adopt the concept of sustainable green construction had to be improved while the organization must emphasize increasing efficiency.*

The relatively consistent score performed by all projects indicated that they had the same problems in executing a project. The first problem was that the low performance of productivity that caused by the need improvement of all projects in completing the indicator of the material selection and utilization (index = 2.83).

The second concern was efficiency that which cause could be traced back to the efficiency index. In the factor Waste Minimization, all projects had to meet the criterion of the indicator of the application of the environmentally friendly product (index = 3.32), the use of pre-fabrication construction element (index = 3.67), and the comprehensiveness of construction design and planning (4.43).

In the factor sustainable green construction, almost all of projects had to meet the criterion of the indicator of the documentation of reusing and recycling of construction waste (index = 4.32), but the utilization of recycled material

(index = 2.83), and the maximization reuse of component building (index = 2.83), both need improvement to increase the index. The third problem related to awareness was caused by the failure of all projects to fulfill the factor of environmental performance on construction site especially on the indicator of water pollution control (index = 2.9), meanwhile the noise pollution control (index = 3.77) included in the good category. The problems related to the factor of understanding of construction waste were caused by the establishment of reward & punishment based on environmental requirements (index = 2.93). Een though the training of construction waste reduction (index = 4.67), and the awareness of construction equipment implication to the environment (index = 4.79) showed a significant difference.

As the awareness index was the highest one, it could be concluded that the willingness and commitment to achieve the sustainable green construction concept had developed among the personnel involved in the project. However, the motivation developed was in line with the field implementation as shown by the efficiency index (4.01) also the productivity and awareness index showed its relatively excellence performance.

4. Conclusion

The results of the assessment of the five highrise buildings can be seen from from two perspectives. The Green Construction Site Index measuring efficiency, productivity, and awareness from three types of building. The first is performance of five projects assessed, all of projects included in excellent category but project #1 just reach smallest index (4.07).

The second perspective was commitment index of personnel within the organizational structure from five projects assessed include in excellent category with smallest index was procedural level (4.12).

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