Sustainability Performance Of Building Construction Projects In Indonesia

by Betty Susanti

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Betty Susanti, Febrian Hadinata, Citra Indriyati

Abstract: This study aims to build a performance map of various sustainability criteria for building construction projects. The criteria related to the appropriate site development category; material resources and cycle; and indoor health and comfort category have high sustainability performance; while criteria related to water conservation, energy efficiency and conservation, and building environment management still have low performance. Criteria related to the use of wood materials from legal trade sources, the use of materials originating from regional areas, and restrictions on chemical pollutants at the project site have been well implemented at the project site. There are other criteria that still have low performance, which are related to the low efforts to reduce heat island effects, the absence of rainwater storage from building roofs, the absence of effort to use the used materials, the limited use of environmentally friendly materials, the limited use of prefabricated materials, and the absence of a construction waste management plan.

Index Terms: buildings, construction projects, performance map, sustainable construction.

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1. INTRODUCTION

Construction work is believed to contribute positively to social and economic aspects, but can also have a negative impact on the environment [1]; [2]; [3]; [4]; and [5]), due to the high consumption of basic materials derived from nature (such as cement, wood, aggregate), high consumption of water and energy for the construction process, the amount of waste generated from the construction process, and the high carbon emissions resulting from the process of processing construction materials and the construction process itself [6]; [7]; [8]; [9]; and [10]. Along with the more increasing construction activities, the more significant impact it has on the environment. Thus, efforts are needed to minimize the negative impacts of construction work on reducing global environmental conditions. One effort is to apply the principle of sustainable construction. Sustainable construction is a philosophy associated with construction management and project management that aims to provide a balance of environmental, social and economic aspects [9] and [11]. According to [12], [13], and [14], sustainable construction is a development concept that meets current needs by paying attention to the ability to meet future generations' needs which also has environmental, social and economic dimensions. The conceptual framework of sustainable construction as developed by [15] shows that the principles of sustainable construction must be applied to various resources used in construction work, which includes land, materials, water, energy, and ecosystems. Based on [7], there are currently a few construction industry players who understand the proper implementation of sustainable construction principles. Ref [12] also showed that current construction projects still do not fully apply the principles of sustainable construction. Given the construction work of buildings and infrastructure facilities that continue to increase globally, efforts are needed to improve the sustainability of construction projects. Performance reviews on the application of various sustainability criteria from construction projects are urgently needed to provide an overview regarding the level of implementation of the sustainability criteria at the project site; to support the implementation of sustainable construction concept appropriately; and as a preliminary study to provide a strategy to increase the sustainability of construction activities.

Indonesia is one of the countries in Southeast Asia that has the highest construction market compared to its neighboring countries. Data from the Indonesian Central Bureau of Statistics in 2018 shows that around 35% of the construction works are building construction, while the rest is the construction of infrastructure and other civil buildings. One of the cities in Indonesia that is actively pursuing the development is Palembang City, namely the provincial capital in the southern of Sumatra island. This city is the second city for the organizers of the 2018 Asian Games in addition to Jakarta City which is the capital of the State of Indonesia. Various infrastructure facilities such as roads, bridges, light rail transit, and various buildings were built to support the holding of the event. Based on the description above, it is necessary to evaluate the performance of various sustainability criteria in building construction projects. This study aims to produce a performance map for sustainability criteria implementation for building construction projects, as a first step to improve sustainability performance in construction projects.

2 LITERATURE REVIEW

The construction industry is able to make a positive contribution to social and economic aspects, but also has the potential to have a negative impact on the environment. Construction work has been proven to carry out extensive exploitation of natural resources and contribute significantly to waste production [6]; [7]; [8]; [10]; [1]; [4]; [16]). Over the past few years, concern for sustainable construction is increasing, so that construction work is required to be able to apply the concept of sustainable construction [17] and [18]. Although the drive to implement sustainable construction continues to increase, the practice of applying the sustainable construction principles by developers, consultants, and contractors often fails. Sustainable construction is an effort to create and manage a built environment by using resources efficiently and applying ecological principles, so that it can provide a balance of environmental, social and economic impacts [19] and [20]. Sustainable construction can be carried out in various aspects, starting from appropriate site planning, organizational planning, procurement and use of materials, construction waste management, minimization of energy consumption, and

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various other efforts related to efficient use of natural resources. Based on [21], sustainable construction must be built on the principles of sustainable development and the right construction perspective. Ref [15] has developed a framework for sustainable construction as shown in Figure 1. Based on the framework of sustainable construction, there are 7 principles of sustainable construction that can be applied along the project life cycle; and the sustainable construction principles must be applied to various resources needed for the construction and for the use of the built environment.

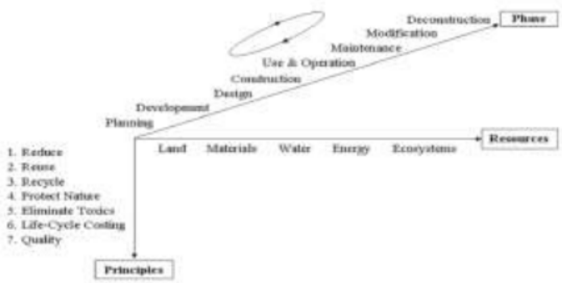

Fig 1. *Framework for Sustainable Construction (Ref. [15]).*

An assessment of the sustainability level of a construction project is difficult, as shown in [11], because it must involve various integrated indicators and must show a broad range of development goals [22]. However, various sustainability rating systems or building assessment methods have been developed to assess the contribution of buildings to the principle of sustainable construction. The most extensive valuation method used to assess the sustainability of buildings is BREEAM (Building Research Establishment's Environmental Assessment Method) developed in the UK. This method is the basis for developing other assessment methods such as LEED (Leadership in Energy and Environmental Design) in the US, CASBEE in Japan, GREEN STAR in Australia, and HQE in France, HK-BEAM in Hong Kong, and Greenship in Green Building Council (GBCI) Indonesia, who have included adjustments to the regulatory aspects, policies, and conditions of each country. Until now, various techniques and methods for assessing the sustainability of buildings are more biased towards environmental aspects [23] and [24]. The assessment categories used generally include the categories of energy, environmental quality, waste, water and material management. Although the categories used tend to be in the assessment of environmental aspects, however the use of this method can contribute positively to increase sustainable construction, as stated in [25].

3 METHODOLOGY

This research was carried out with the stages as shown in Figure 2. The initial stage was to assess the implementation or performance of all sustainability criteria in all building projects. The sustainability criteria used are the criteria found in the Greenship of GBCI. Case studies were carried out on 12 building projects, which consist of multi-storey residential buildings, hotels, campus buildings, and hospitals. The selection of a case study projects is based on the consideration of the progress of the construction work is at the finishing stage, or projects at handover phase, or projects that have been completed and are operating for less than one year.

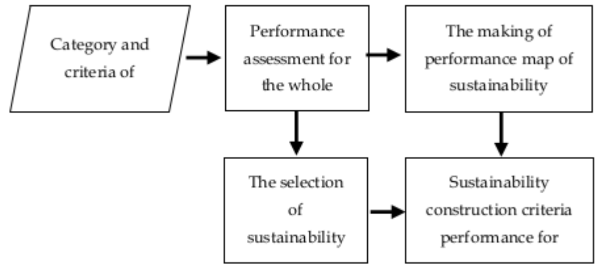

Fig 2. *Research Stage*

The results of the performance assessment for all sustainability criteria was then plotted in the performance map. Criteria with an average performance or level of application ≥ 50% of the expected minimum performance, classified as high performance sustainability criteria; and vice versa. In this study, the expected minimum performance value is the average performance value of each criterion reviewed. This average value is obtained from the total score of all indicators divided by the number of indicators contained in each criterion. Sustainability performance was also analyzed to determine their respective roles throughout the project life cycle. The selection of these criteria is intended to obtain various criteria related to construction phase or to determine the sustainable construction criteria. This stage provides an overview of the performance of various sustainability criteria, whether the implementation in the field has been good or still low.

4 PERFORMANCE ASSESSMENT OF THE SUSTAINABILITY CRITERIA

Performance assessment was carried out on 38 sustainability criteria in GBCI's greenship. The criteria are included in the categories of appropriate site development (ASD), energy efficiency and conservation (EEC), water conservation (WAC), material resources and cycle (MRC), indoor health and comfort (IHC), and building environmental management (BEM). Table 1 shows the categories, criteria, and expected minimum performance values for each criterion.

Table 1. *Sustainability Assessment Indicators*

No	Category and Assessment Criteria		Minimum performance value
Appropriate Site Development-ASD			
1	ASD 1	Site selection	1
2	ASD 2	Community Accesibility	1.5
3	ASD 3	Public Transportation	1
4	ASD 4	Bicycle Facility	1
5	ASD 5	Site Landscaping	1
6	ASD 6	Micro Climate	1
7	ASD 7	Stormwater Management	1.25
Energy Efficiency and Conservation-EEC			
8	EEC 1	Energy Efficiency Measures	1.25
9	EEC 2	Natural Lighting	2
10	EEC 3	Ventilation	1
11	EEC 4	Climate Change Impact	1
12	EEC 5	On Site Renewable Energy	1
Water Conservation-WAC			
13	WAC 1	Water Use Reduction	1
14	WAC 2	Water Fixtures	1
15	WAC 3	Water Recycling	2

No	Category and Assessment Criteria		Minimum performance value
16	WAC 4	Alternative Water Resources	1
17	WAC 5	Rainwater Harvesting	1
18	WAC 6	Water Efficiency Landscaping	1
Material Resources and Cycle-MRC			
19	MRC 1	Building and Material Reuse	1
20	MRC 2	Environmentally Friendly Material	1
21	MRC 3	Non ODS Usage	2
22	MRC 4	Certified Wood	1
23	MRC 5	Prefab Material	3
24	MRC 6	Regional Material	1
Indoor Health and Comfort-IHC			
25	IHC 1	CO_2 Monitoring	1
26	IHC 2	Environmental Tobacco Smoke Control	2
27	IHC 3	Chemical Pollutant	1
28	IHC 4	Outside View	1
29	IHC 5	Visual Comfort	1
30	IHC 6	Thermal Comfort	1
31	IHC 7	Acoustic Level	1
Building Environment Management-BEM			
32	BEM 1	Green Professional as a Member of Project Team	1
33	BEM 2	Pollution of Construction Activity	1
34	BEM 3	Advanced Waste Management	1
35	BEM 4	Proper Commisioning	1.5
36	BEM 5	Green Building Submission Data	1
37	BEM 6	Fit Out Agreement	1
38	BEM 7	Occupant Survey	2

4.1. Performance Assessment for ASD Category

The results of the performance assessment of all sustainability criteria for the ASD category are shown in Figure 3. There are 2 criteria that have met sustainability performance well, those are site selection (ASD 1) and public transportation (ASD 3) criteria. The entire building that was reviewed was built on the land that is in accordance with land use, has good accessibility with public facilities, and has provided easy access to public transportation facilities.

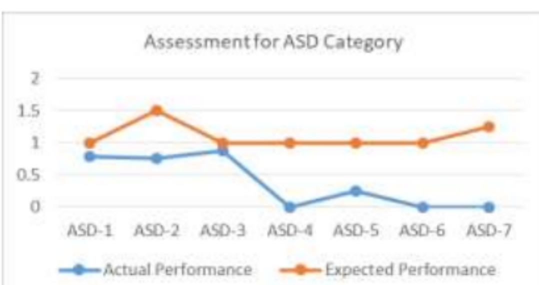

Fig 3. *Sustainability Performance Assessment for ASD Category*

There are 5 criteria that still have a low sustainability performance or low level of implementation at the project site related to community accesibility (ASD 2), bicycle facility (ASD 4), site landscaping (ASD 5), micro climate (ASD 6), and stormwater management (ASD 7). In the ASD 2 criteria, community accessibility is available for various public facilities around buildings within a radius of 1,500 meters. However, the distance from the building to the public facilities is still more than 300 meters. The assessment also shows that pedestrian access to and from buildings is still limited, due to security considerations in the building. In the ASD 4, the provision of bicycle facilities in most buildings is still very limited because the use of bicycles in Palembang City has not become the main mode of transportation for building users. Assessment of the ASD 5 criteria also shows that most of the buildings reviewed has not provided a landscape area at least 40% of the total area, because most of the landscape area are hardened for the purposes of the parking area. All projects reviewed in this study show that there is no consideration of climate impact reduction (ASD 6) in the design and construction phase of buildings. The use of building materials for roofs and non-roof pavement areas has not considered the reduction of heat island effects. This is due to the limited understanding of the owners and project planners regarding the use of materials with low heat island effects. The construction of the building has not yet implemented the management of rainwater runoff (ASD 7), so that rainwater runoff from the building site is still fully charged to the city drainage network.

4.2. Performance Assessment for EEC Category

The sustainability performance assessment in Figure 4 shows that building design in general has considered the use of ventilation (EEC 3) in toilet rooms, stairs, and corridors, both for air circulation and for lighting purposes. However, there are still 4 other criteria that have not yet achieved good performance. In EEC 1 criteria, there is no effort to calculate energy consumption in buildings, even though the awareness of the owners and managers of buildings regarding the efforts to save energy is very high. The concrete and significant steps taken by the building owners and managers are currently limited to the use of energy-saving features in vertical transportation equipment, air conditioners, and other electronic equipment. In the natural lighting criteria (EEC 2), less than 30% of the building floor area generally receives inadequate light, so that in some rooms it requires additional lighting from the lamp.

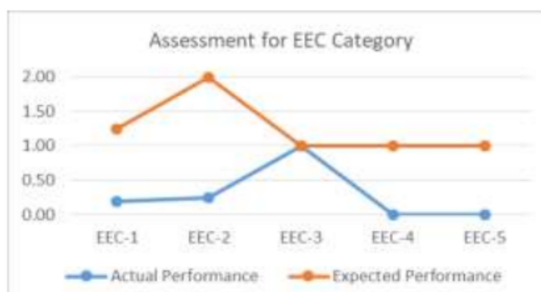

Fig 4. *Sustainability Performance Assessment for EEC Category*

Although there is awareness from the owners and managers of buildings related to the importance of saving energy, there has not been any real effort to utilize new and renewable energy sources as indicated in the EEC criteria. 5. The same thing is also applied to EEC criteria 4, even though there is an understanding from parties involved in building construction regarding the effects of energy consumption on climate change, but the calculation of CO_2 emissions associated with energy use has never been done.

4.3. Performance Assessment for WAC Category

Sustainability assessment for the water conservation category shows that all the buildings reviewed still have performance that is below the expected sustainability performance, as shown in Figure 5. In most of the building projects reviewed, there is no attempt to reduce dependence on primary water sources to meet the needs of clean water, as indicated by the WAC 1. However, there has been awareness of the owners and managers of buildings to use water features which can limit the clean water discharge capacity below the maximum standard, as indicated by WAC 2. Most of the reasons for using water features with discharge capacity below this maximum standard are in the aspect of saving building operational costs, not based on consideration of environmental aspects. In general, the use of water features that have effluent capacity efficiency still does not reach 25% of the total procurement of water feature products.

Fig 5. *Sustainability Performance Assessment for WAC Category*

Among 12 building projects reviewed in this study, there is one hotel building that has considered the use of recycled water by building a water treatment plant (WTP). Recycled water by WTP is then used for the purposes of flushing and building drainage. Other buildings have not yet used recycled water as required by WAC 3 criteria. All buildings reviewed show that there is no attempt to use alternative water sources (WAC 4) and the absence of rainwater storage efforts (WAC 5) as a step to reduce water consumption from primary sources. This is due to the lack of experience and understanding from the owners and managers of buildings related to technology understanding of alternative water sources and rainwater storage. The survey results also show that there is no effort to use landscape water (WAC 6) efficiently, because all water used for building irrigation comes from primary water sources.

4.4. Performance Assessment for MRC Category

The assessment in this category is generally directly related to the process of building construction. The results of the assessment for this category are shown in Figure 6. Construction of buildings in general has not utilized used materials as main structural materials, facades, ceilings, floors, partitions, frames, and walls; as indicated by the assessment for MRC 1 criteria. Surveys conducted on all case study projects indicate that the limited use of prefabricated materials or modular materials (MRC 5). The limited use of recycled materials and prefabricated materials is due to the limited experience of the project owners regarding the use of these materials.

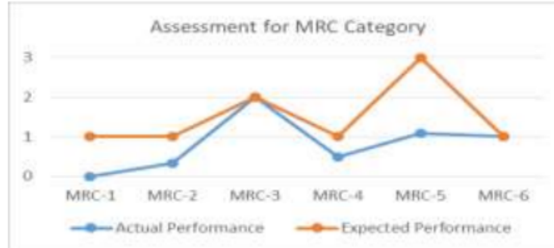

Fig 6. *Sustainability Performance Assessment for MRC Category*

Building owners and planners also have not considered the use of environmentally friendly material (MRC 2) yet, although there is awareness of the parties involved in the project related to the importance of using environmentally friendly materials. The selection of building materials by the parties involved in the project has not been based on consideration of the ecological footprint and the process of extracting raw materials in the material production process itself. The use of building materials derived from wood-based materials as in the MRC 4 criteria also has not considered certificates from ecolabel institutions, although the origin of wood is ensured from the legal trading process. The survey results on all case study projects show that there are two sustainability criteria that have actual performance as expected. Overall, the projects reviewed have considered the use of materials where the location of raw materials and factories is not far from the project location (MRC 6), to avoid the high costs of procuring and transporting material to the project location. In addition, building operations also do not use refrigerants which have the potential to damage ozone, as required by MRC 3 criteria.

4.5. Performance Assessment for IHC Category

The results of the performance assessment for this category are shown in Figure 7. There are three criteria that have good sustainability performance, those are the control of tobacco smoke in the building (IHC 2); control of chemical pollutants (IHC 3) such as in the use of paint, the use of composite wood, lamp materials, and non asbestos materials; and the criteria related to indoors visual comfort (IHC 5). The assessment of IHC 3 criteria shows that there has been awareness and understanding of the parties involved in the project to reduce the negative impact of chemical pollutants produced during the construction phase.

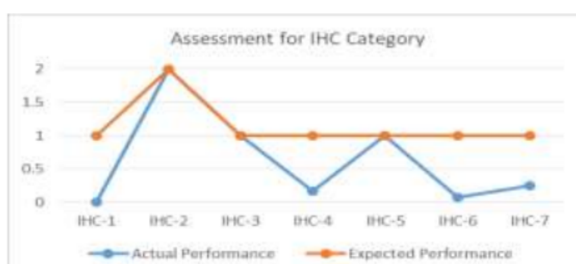

Fig 7. *Sustainability Performance Assessment for IHC Category*

In addition to these three criteria, there are four other criteria that still have low performance, which are related to the criteria of IHC 1, IHC 4, IHC 6, and IHC 7. Surveys conducted on all buildings indicate that there is no effort to monitor CO_2 levels in the building area. Building designs in general have not provided adequate access to outdoor views. Design in commercial buildings generally maximizes the number of rooms, so that the outdoors view of the building is limited. The survey also shows that there is no concrete and consistent effort from the building owners to maintain the stability of temperature and humidity as well as controlling noise in the building.

4.6. Performance Assessment for BEM Category

In general, there has been no effort to reduce waste and pollution from construction activities, as indicated by the assessment of BEM 2. Each project reviewed does not have a construction waste management plan. Solid waste is generally disposed without prior separation, while liquid waste from the construction process is generally disposed into the city drainage network. In line with the results of the assessment on the BEM 2 criteria, all projects reviewed also did not manage organic or inorganic waste generated from building operations, as indicated by the assessment of BEM 3. The building commissioning system (BEM 4) has generally been well implemented. For leased buildings, there is an agreement process as outlined in the lease agreement and there is a standard procedure document for building operations and maintenance (BEM 6). The survey conducted on the building owners and managers shows that in general the building user satisfaction survey has not been carried out, as required in the assessment of BEM 7 criteria. The results of the sustainability performance assessment for the building environment management category are shown in Figure 8. All projects reviewed did not involve experts who had greenship professional certificates (BEM 1) and did not submit green building implementation data (BEM 5). These two criteria are not applied to all projects reviewed because the projects reviewed are not intended to be assessed by GBCI.

Fig 8. *Sustainability Performance Assessment for BEM Category*

5 PERFORMANCE MAP OF THE SUSTAINABILITY CRITERIA

All sustainability criteria that have been assessed were then plotted in the performance map as shown in Figure 9. Among the 38 criteria assessed, as many as 11 criteria have high performance with a performance value or level of implementation at the project location ≥ 50% of the expected minimum performance value. The sustainability criteria with a high performance are generally related to the category of appropriate site development (on the criteria of ASD 1, ASD 2, and ASD 3); material resources and cycle categories (on the criteria of MRC 3, MRC 4, and MRC 6); indoor health and comfort category (on the criteria of IHC 2, IHC 3, and IHC 5); EEC 3 criteria; and BEM 4criteria. These various categories have high performance values due to the high level of awareness and understanding of the parties involved in the construction process and building operations related to the implementation of various sustainability criteria. This is in line with [26] and [27], who showed that those various criteria have been generally implemented well on the buildings construction and operation phase.

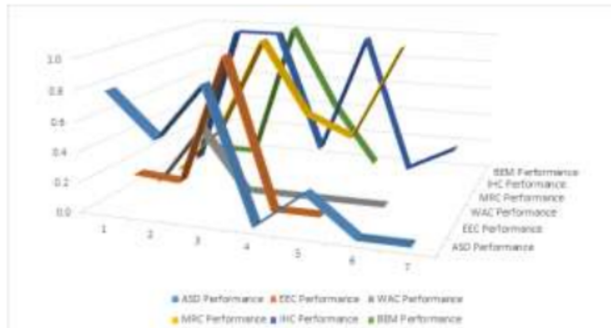

Fig 9. *Performance Map of Building Sustainability Criteria*

The assessment also shows that there are 27 criteria that have low performance, as indicated by the level of implementation of these categories at the project location is less than 50% of the expected minimum performance value. Categories related to water conservation, energy efficiency and conservation, and building environment management are dominant categories that have low performance levels. The low implementation of various sustainability criteria is due to the low understanding of the project owners and planners regarding water and energy conservation technologies; and the low awareness of the parties involved in the construction and operation of buildings to manage waste before being disposed to landfills. This is in line with the review study conducted by [28], [29], [30], [31], and [32] who showed that those various criteria have not been generally implemented well on the building consruction and operation phases. Based on [33], sustainability should be considered throughout the project life cycle. The selection and grouping of sustainability criteria in each project life cycle is shown in Table 2. The criteria that play a direct role in the construction phase as generated from this selection process are then grouped as sustainable construction criteria. There are 9 criteria for sustainable construction as shown in Table 2.

Table 2. *The Role of Sustainability Criteria along the Project Life Cycle*

Sustainability Criteria	Project Life Cycle			
	Planning Phase	Construction Phase	Commissioning Phase	Operation and Maintenance Phase
ASD 1	√			
ASD 2	√			
ASD 3	√			√
ASD 4	√			√

ASD 5	√			
ASD 6	√	√		
ASD 7	√			
EEC 1	√			√
EEC 2	√			√
EEC 4	√			√
EEC 5	√			√
WAC 1	√			√
WAC 2	√			√
WAC 3	√			√
WAC 4	√			√
WAC 5	√	√		
WAC 6	√			√
MRC 1	√	√		
MRC 2	√	√		
MRC 3	√			√
MRC 4	√	√		
MRC 5	√	√		
MRC 6	√	√		
IHC 1	√			√
IHC 2	√			√
IHC 3	√	√		√
IHC 4	√			√
IHC 5	√			√
IHC 6	√			√
IHC 7	√			√
BEM 1	√			
BEM 2	√	√		
BEM 3	√		√	√
BEM 4	√			
BEM 5	√			
BEM 6	√			√
BEM 7	√			√

In general, the sustainable construction criteria are closely related to the material resources and cycle category, which are the use of used materials as construction materials (MRC 1), the use of materials obtained from extraction processes that are environmentally friendly and the use of recycled materials (MRC 2); the use of certified materials from the ecolabel institution (MRC 4); the use of modular or prefabricated material (MRC 5); and the use of local materials (MRC 6). There are other sustainability criteria related to the construction phase, which are related to the use of materials that can reduce the heat island effect (ASD 6); provision of rain water storage installation (WAC 5); use of building materials with low pollution and emission levels (IHC 3); and the implementation of construction waste management for solid and liquid waste, as indicated in the BEM 2 criteria. Among the nine criteria related to sustainable construction, as many as 3 criteria have been applied well in the project location so that they have high sustainability performance, while the other 6 criteria still have low sustainability performance due to the low implementation at the project location. The criteria with high performance are related to MRC 4, MRC 6, and IHC 3; while the criteria ASD 6, WAC 5, MRC 1, MRC 2, MRC 5, and BEM 2 has low performance, so it needs to be studied further to determine the sustainability improvement strategies.

6 CONCLUSION

This research has generated a performance map of building sustainability criteria. There are 11 sustainability criteria which have high performance and have been well implemented in the construction and operational of buildings, but as many as 27 criteria still have low performance. In particular, this study also generated a performance map for sustainable construction criteria. There are 9 criteria that are directly related to the construction process. The 3 sustainable construction criteria have high performance, which are related to the use of wood materials from legal trade sources, the use of materials originating from regional areas, and restrictions on chemical pollutants at the project site. Six other sustainable construction criteria still have a low performance or low implementation at the project site, which are related to the low effort to reduce heat island effects that can improve the quality of microclimates, the absence of rainwater storage from building roofs as an effort to reduce dependency towards primary water sources, the absence of efforts to reuse used materials, the limited use of environmentally friendly materials based on ecological footprint considerations in the material production process itself, the limited use of prefabricated materials, and the absence of construction waste management plans that can affect the pollution from construction activities. The performance map of the sustainability criteria that have been generated from this study can be used as a consideration to develop strategies to improve sustainability performance in building construction projects.

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