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Development of a sustainability rating tool for heritage buildings: future implications

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ABSTRACT

Purpose – Heritage buildings are significant for their historical and architectural value. Due to the lack of rating systems designed specifically for heritage buildings, it is essential to develop and validate a heritage building assessment tool that considers its specific characteristics. The purpose of this study is to provide an extensive review of research on Sustainability of Heritage Buildings (SHBs).

Design/methodology/approach – This review highlights methodologies applied in SHBs research and analyzes major global rating systems in order to identify their deficiencies for SHBs assessment. A systematic review was employed and articles from the top 10 high impact factor journals were studied. Twelve major global rating systems and their assessment criteria were identified.

Findings – Significant variability was observed among the assessment tools since each tool assesses several criteria, factors and indicators that fit its local context. Part of this variability can also be seen in the rating scales, threshold values and accreditation titles. As a result, the final sustainability ranking for a given building cannot be compared among the 12 rating systems. Most importantly, these systems fail to analyze some factors such as energy that are considered important with respect to heritage building assessment.

Originality/value – Since no specific rating system could be identified in this review as the most appropriate for heritage buildings, a new sustainability assessment tool that is specific to heritage buildings should be developed. Such a tool will enable facility managers to evaluate and improve the sustainability of their heritage buildings while preserving them.

Keywords– Heritage buildings, Sustainability assessment, Rating system, Architectural heritage, Systematic review

Paper type– Research paper

1. INTRODUCTION

1.1 Heritage buildings: Definition

Heritage buildings are recognized as integral parts of today's society. They comprise of notable edifices and structures of historical and architectural value (Giovine, 2019). The historical integrity, importance, and context dictate whether or not a structure is categorized as heritage (UNESCO, 2018). The integrity of a heritage building refers to the conservation of parts of the building with respect to its historical time frame. The importance of a heritage building refers to its historical, archaeological or cultural value based on historically significant people or incidents that are associated with it (Jokilehto, 2006; Central Public Works Department, 2010; Dawoud & Elgizawy, 2018).

1.2 Current Status

The Saudi Commission for Tourism and National Heritage reported that there is an absence of a plan to maintain the upkeep of heritage buildings, which in turn has led to almost half of these buildings being in need of repair (SCTNH, 2012). It is, therefore, necessary to develop a sustainability rating system that would aid in the maintenance of heritage buildings. This system will also take into account socio-economic factors related to heritage buildings. In the Middle East, for example, internationally accepted rating systems such as BREEAM and LEED cannot be employed since the local contexts and climate are different. The aim of this research is to enable the evaluation of the sustainability of heritage buildings.

2. RESEARCH OBJECTIVES

Recent publications on the Sustainability of Heritage Buildings (SHBs) were studied as well as the rating systems used in evaluating the sustainability of heritage buildings. Research objectives include:

i. Establish systematic reviews for literature review on heritage buildings

ii. Compare existing rating systems for sustainable buildings
iii. Identify different criteria, factors and indicators that are considered in the rating systems
iv. Review different methods applied to calculate ratings
v. Investigate different rating scales in each rating system.

3. LITERATURE REVIEW

Sustainability of heritage buildings is the main focus of this review. Existing sustainability rating systems such as BREEAM and LEED are not adequate for sustainability assessment of heritage buildings since these systems do not consider energy and cost-efficiency in their assessment (Akande, 2015). The literature review is performed as follows:

1. An analysis of the definition of heritage buildings, types, and conservation treatments.
2. An enumeration of the current standards and guidelines for sustainability of heritage buildings.
3. An examination and comparison of current rating systems that have been employed to evaluate sustainability of heritage buildings.

3.1 Heritage buildings: assessing energy requirement or consumption

Energy requirement of a building refers to the energy needed or utilized for the building to function (Akande, 2015). It is influenced by several factors that either lead to the production or consumption of energy in the building. For many buildings, energy efficiency is desirable in order to decrease its carbon footprint (DCLG, 2006). Energy efficiency can be measured for newly constructed buildings as well as heritage buildings. However, dissimilarities exist in the way energy efficiency is calculated due to various modeling and analytical methods that are employed when analyzing the energy requirement or consumption in heritage buildings (Moran et al., 2012; Baker, 2011; Klemes, 2015). Moran et al. (2012) also mentioned that certain software used to analyze energy efficiency have a built-in inflexibility and can lead to biased and erroneous energy efficiency ratings for older buildings. Heritage buildings are then ultimately categorized as either good (Ndoro, 2008; Stba, 2012) or poor (DECC, 2014; Government., 2009; Killip, 2008) in terms of energy performance.

3.2 Heritage buildings: foundations

3.2.1 Definitions

Heritage buildings have been defined in different ways in literature. Definitions were provided based on the local context and other factors such as age, environment, and architectural elements (Kalman, 1980). Although discrepancies exist, there are four main distinguished definitions.

Heritage buildings have been associated with the term cultural heritage. In 1972, UNESCO elaborated on this term by referring to buildings, artworks, structures or monuments that have a significant artistic, historical or scientific value (Ahmad, 2006). Heritage buildings can exist as a stand-alone building, that is, single or a group of connected buildings that share the same architectural elements or located in the same place on the landscape. Some heritage sites are man-made; however, others are as a result of climate and environmental changes. Some heritage areas can include more than one archaeological site (UNESCO, 1972). Version 7 of the UNESCO document refers to heritage mainly from a horizontal perspective, as being handed down from generation to generation, and patrimonies describe heritage from a social context. To account for the overall reality, the definition of heritage should also include a vertical perspective (Bree, 2010; UNESCO, 2009; Zancheti & Similä, 2012).

‘Heritage’ was initially defined in 1964 in Venice. It was introduced as "Imbued with a message from the past, the historic monuments of generations of people remain to the present day as living witnesses of their age-old traditions" (Bree, 2010). The terms *monuments* and *sites* have also been included in the definition of heritage. Monuments are defined as buildings or areas, along with their contents, that are significant from a historical, architectural or archaeological perspective (Zancheti & Similä, 2012). A site refers to a natural and/or man-made location or structure that the public is willing to preserve (Koeman, 1990). In 1968, cultural property was described as ‘movable’ (for example, collections in museums) or ‘immovable’ (for example, historically significant buildings), with the latter to include traditional structures present in cities and villages (Ndoro, 2008).

The Council of Europe in 1975 defined the scope of heritage, which was later modified in 1979 by the Burra Charter to include:

- Cultural importance in terms of social, scientific or historical contexts;
- Fabric, which refers to physical contents of a given place; and
- Place, which refers to building or area together with its contents and environment (UNESCO, 1972).

Countries like Australia and New Zealand have limited their definition of heritage to include places. However, China describes its concept of places designated as heritage as: “the immovable physical remains where they have been created during the history of humankind, and this has significance”. In this context, immovable comprises of historical ancient towns, debris, sepulchers, and structures (Ahmad, 2006). Other Southeast Asian countries describe the term cultural heritage by referring to “structures and artifacts, sites and human habitats, oral or folk heritage, written heritage, and popular cultural heritage” (Museums, 2001). Specifically, in Vietnam, heritage consists of “tangible and intangible cultural heritage” while the Philippines includes both “movable and immovable” heritage (Ahmad, 2006).

In the 1964 Venice charter, a number of recommendations were proposed to aid the definition of the scope of the term heritage, but there still lacks a consensus in the definition for all countries (Inventory, 2004). Although these two organizations, International Council on Monuments and Sites (ICOMOS) and UNESCO, both acknowledge that heritage must include ‘cultural’ (that is, structures or buildings) and ‘natural’ heritage (Göttler & Ripp, 2017), this remains yet to be accepted internationally. Ahmad (2006) states that although there was an international agreement on including terms like 'tangible,' 'intangible' and 'environments’ to define the term heritage, there is no unified and consistent definition that is applicable to all countries. For example, in Australia, heritage includes “place, cultural significance, and fabric”; in Canada, it includes “material culture, geographic environments, and human environments”; in New Zealand, it includes “place”; and in China, it includes “immovable physical remains” (Ahmad, 2006). Countries have the liberty to define several terms, but it is necessary that a uniform norm be developed. Hence, UNESCO and ICOMOS were advised to discuss the establishment of a scope and standard terminologies and definitions, which countries will be requested to later implement (Göttler & Ripp, 2017).

4. RESEARCH METHODOLOGY

The goal of this review paper is to compare different rating systems used around the world and expound on how they can be tailored and applied to fit the unique nature and characteristics of SHBs. The research method addresses all factors, indicators, and sub-indicators that permit the analysis of the sustainability of heritage buildings. The research methodology employed in this paper involved the selection of databases, keywords, and top ten journals in the field of SHBs (Figure 1). More specifically, a systematic review was employed. Primary sources were published journal articles as well as different handbooks and reports on the studied rating systems that are employed by several organizations.

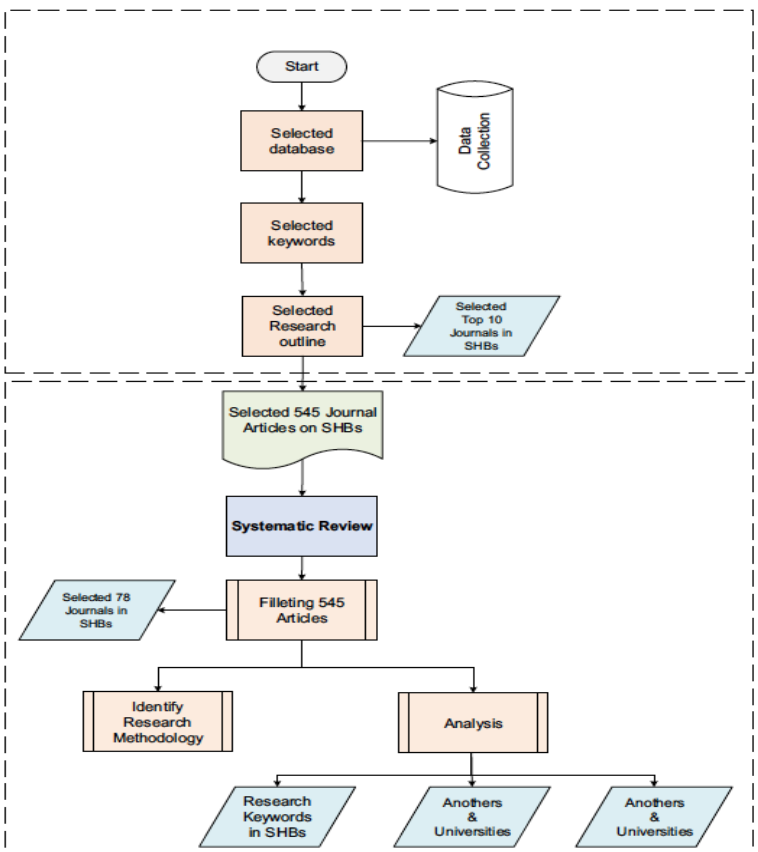

Fig. 1: Rsearch methodology flowchart

Systematic Review Procedure

The systematic review procedure follows five predefined steps - problem questions are enumerated; literature search is performed without any language restrictions to compile relevant studies; quality of relevant studies is assessed by leveraging an assessment criterion to identify the main contribution, strengths and weaknesses of the work; all study characteristics, impacts, and contribution are tabulated; and finally, findings from studies are interpreted to identify biases, gaps and overlaps. For the literature search, there is a two-step screening process. First, the number of abstracts that are screened (after duplicates) is reported and then the number of abstracts whose full-text are chosen to be read is reported. Second, the number of full-text articles that are included in the final review/analysis is reported.

Results from database search were required to include at least one term from each of the three groups of keywords for the following main concepts: 1) Sustainability, 2) Heritage/Cultural Buildings, and 3) Rating Systems/Information Modeling. For example, *Sustainable* AND ("heritage building*" OR "architectural heritage" OR "cultural heritage") AND ("rating system*" OR classification OR "information modeling" OR Assessment OR "Heritage Building Information Modeling" OR HBIM).* Database search was conducted by a library science expert and followed standards first articulated by Cooper (1998), and later developed into a set of best practices by the Campbell Collaboration (Kugley et al., 2017; Pickup et al., 2018). Wherever possible, the methodology for database search was modified to suit the requirements of each database by using official controlled vocabulary subject headings or publication type filters (for example, to remove magazine and newspaper articles).

The search in bibliographic databases was supplemented by a separate strategy to locate grey literature (Farace & Schöpfel, 2010). The primary tool employed for this later search was the Google search engine. When scholarly books and conference proceedings were found, their tables of content were scanned for additional relevant information. An exhaustive single search statement is not possible using Google; hence, several search requests were run, varying the keywords employed. For example: *sustainability rating system heritage,* ‘*sustainability rating system "Heritage Building*

Information Modeling", ‹sustainability "cultural heritage" "information modeling" . Overall, a total of 1533 results were generated, of which 990 abstracts were retained for review after duplicates were removed. After selecting the top 10 high-impact factor journals, only 78 papers were found to be published from 1990 to 2020 and were related to SHBs.

5. RESULTS AND DISCUSSION

In this section, results are presented to highlight yearly publications from universities and other institutions involved in SHBs research. Methdologies employed in SHBs research are also described.

5.1 Selected Keywords and Journals

Since keyword search has proven to be an effective means for literature retrieval from various search engines (Deng & Smyth, 2013), the most common and interchangeable keywords related to SHBs were used to extract a more comprehensive set of bibliographic data on SHBs. For instance, the keywords used for the search include *sustainability rating system heritage, ‹sustainability rating system "Heritage Building Information Modeling"* HBIM*, ‹sustainability "cultural heritage," "information modeling,"* and "*renovation"*. These keywords were retrieved based on the abstracts of the 78 papers from the systematic review (Table 1). Efforts were made to use keywords which can assist in retrieving almost all the journals and papers on SHBs. The selected top ten journals in SHBs include *Journal of Cultural Heritage, International Journal of Architectural Heritage, Sustainability, Sustainable Cities and Society, Sustainable Development, Engineering Construction, and Architectural Management, Building and Environment, Heritage Science, and International Journal of Heritage Studies*. Only papers in English were incorporated (Table 1). Of these journals, *Building and Environment* and *International Journal of Heritage Studies* had the highest and lowest impact factors, respectively. Also, the *Journal of Cultural Heritage* had the highest number of publications while *Sustainable Development* and *Engineering Construction and Architectural Management* had the lowest number of publications.

Table 1: Methodologies applied in the in SHBs research

Methodology	Paper	Technique
Simulation	Fahmy *et al.* (2014), Tiwari *et al.* (2016), Pisello *et al.* (2016)	Software® + SRCs
	Yildirim and Bilir (2017), Attar *et al.* (2013), Radhi *et al.* (2013)	TRNSYS + DesignBuilder®
	Fumo and Biswas (2015), Wong *et al.* (2013), Hygh *et al.* (2012)	ArchiCAD® + PVTIGS
HBIM	Pocobelli *et al.* (2018)	Visualization + BIM
	Bruno and Fatiguso (2018), Hygh *et al.* (2012); Kubalikova *et al.* (2019)	Visualization + Simulation + 3D model
	Murphy *et al.* (2013), Ren and Han (2018)	Documentation + Simulation
	Cuperschmid *et al.* (2019), Al-Sakkaf *et al.* (2020)	Simulation + Software®
	Khodeir *et al.* (2016), García-Esparza and Tena (2018)	3D model + Visualization
Visualization	Abanda *et al.* (2013), Fumo and Biswas (2015); Khalil and Stravoravdis (2019)	laser scanner + Virtual prototyping
	Wong *et al.* (2013), Fumo and Biswas (2015); Di Fazio and Modica (2018), Elfadaly and Lasaponara (2019); Alkhalifa (2019)	virtual prototyping + BIM model + GIS
	Khalil and Stravoravdis (2019), Abdelmonem *et al.* (2017)	3D printing + laser scanner
Energy	Tiwariet *et al.* (2016), Attar *et al.* (2013)	Energy analysis + SWHS
Survey	Attar *et al.* (2013), Naamandadin *et al.* (2018)	GHG + Software
	Kehinde (2015), Yildirim and Bilir (2017), Günçe and Misirlisoy (2019)	Documentation + Simulation + Software®
	Yildirim and Bilir (2017), Shamseldin, (2018)	SRCs + PVTIGS
MCDM	Prieto *et al.* (2017), Sanna *et al.* (2008)	Fuzzy logic + AHP
	Sanna *et al.* (2008), Bottero, D'Alpaos and Oppio (2019)	Visualization + ANP
	Alireza *et al.* (2018), De Rosa and Di Palma (2013)	Simulation + Fuzzy logic
	Tupenaite *et al.* (2017), Matute *et al.* (2014)	BIM + AHP

5.2 Yearly Publication on SHBs

It can be observed that for research on SHBs, there was, on average, one paper that was published on SHBs yearly between 2000 and 2010. During the years (2011 to 2020), research on SHBs increased progressively, as seen in the increasing number of research publications per year.

Based on the systematic review, the countries where SHBs research was conducted and the total number of involved universities/institutions, authors, and articles from 2000 to 2020. Italy had the highest number of relevant articles (20) from 24 universities and 53 authors. Co-authorship in SHBs research has also crossed borders. Italy has had ten co-authored research with nine countries: Portugal, Spain, the UK, New Zealand, Netherlands, Brazil, Belgium, Germany, and the Czech Republic. 2 out of the ten corporations were with Belgium. Canada is seventh on the list, having three co-authored research with three countries: Norway, Egypt, and Romania.

5.3 Methodologies employed in SHBs research

From the 78 selected papers, five methodologies were observed to be applied in SHBs research. These methodologies include simulation, Heritage Building Information Modeling (HBIM), visualization, energy survey, and Multi-Criteria Decision Making (MCDM) methodologies. A summary of research gaps and how each methodology was used to solve problems related to SHBs is provided here.

5.3.1 Simulation

In light of the possibility of climate change in the near future, Fahmy et al. (2014) examined the application of GRC walls in building construction in Egypt. They considered three external wall specifications for three different meteorological scenarios based on the effect on the building's thermal conditions, energy efficiency, and cost. Experiments simulated building performance while considering the intrinsic nature of the building materials. Simulation results confirmed the existence of climatic zones. A recommendation of 10 cm GRC (C_2) was specified instead of the usual outer wall specification in Egypt. This specification is that of an individual wall made from half red-brick–Ct since it showed future benefits with respect to energy performance and will thus minimize energy consumption and cost.

By employing the field of computational fluid dynamics, Radhi et al. (2013) also studied the relationship between the energy required to cool a completely-coated building and the application of Climate Interactive © systems. The energy of a new high-rise building was modeled to determine boundary conditions as well as to generate relevant mathematical or computative models. According to Hygh et al. (2012), the energy load of a building can be calculated in a precise way by simulating building models. However, these models cannot be manipulated when the building is still in the preliminary design planning phase. During this phase, there is a need for an assessment tool that is able to provide feedback when the high-level design parameters are varied. The authors then proposed a novel modeling strategy to compute the load (energy-wise) of a building in its primary design stage. They indicated that the utilization of Standardized Regression Coefficients (SRCs) can serve as a useful indicator of how the heating and cooling loads are affected by each design variable.

5.3.2 Heritage Building Information Modeling (HBIM)

HBIM has been an exponentially growing field since the past decade. It has gained momentum with respect to research and case studies that implement relevant models to facilitate modeling, decision-making, and efficient operation of buildings and facilities with a heritage value. Cuperschmid et al., (2019) defined HBIM as a multi-disciplinary field and procedure requiring integration of various personnel with varying skills. Khalil & Stravoravdis (2019) described HBIM as a fast-growing field of research and a continuously improving industry with respect to official guidance, practice and standards. HBIM is generally defined as a model that combines visualizations of multi-dimensions with parametric and comprehensive databases to allow integration of data flow, information and graphical management (Fai et al., 2011).

HBIM is regarded as a highly advantageous model for application in buildings with heritage historical value, as it presents a significant improvement in layout, visualization, approximation of cost, and recognition of discordance (Volk et al. 2014). HBIM can also be helpful in various disciplines to minimize the need for performing a task more than once through rework or duplication, thus saving money and human resources. This also permits interdisciplinary interaction for a given project. Compared to the use of 2D, mapping out a design configuration in HBIM is much more rapid due to its computerized and database-linked tools. Due to its ability to model and identify damaged and missing architectural aspects, HBIM can also be helpful in representing the changes that occur in a heritage building over time (Pocobelli et al., 2018); (Han et al., 2020); (Banfi et al., 2017). HBIM is a proven means of preserving heritage value and conserving the actual heritage building (Lee et al., 2019); (Al-Sakkaf & Ahmed, 2020). This is due to its ability to create specialized physical models that represent a prototype of the actual building. These models are then saved in an electronic form, which will be helpful in building maintenance in case of damage or impairment that may occur in the actual building at any point in the building's lifecycle. Pramanik et al. (2016) and Habibi et al. (2017) also noted improvement in energy and economic analyses of heritage buildings due to the application of HBIM in the sustainability context.

There however exist a few limitations and shortcomings in the implementation of HBIM for historic buildings. HBIM is time-consuming to develop and execute. It has also not been able to model some historic buildings due to irregular geometry and non-homogeneous materials. This in turn adds to the burden of surveying, inspection and documentation processes during the development of HBIM models (Calneryte et al., 2018); (Barazetti and Banfi 2017). Another disadvantage in the execution of HBIM models is that it is difficult to start the model in an intermediate point of the asset's lifecycle. This makes the model highly complex compared to other models that represent newly-built assets in a cradle-to-grave fashion (Khalil & Stravoravdis, 2019).

5.3.3 Visualization

Abanda et al. (2013) reported research gaps in computational modeling and the pertinence of computational models in the calculation of different parameters such as greenhouse gas emissions, energy and cost. Understanding this interrelationship between the model and these parameters will enable analysis and design of sustainable and environmentally-friendly buildings. Wong et al. (2013) described prototype architecture as a means to put in place a system to predict and simulate carbon emission during building projects. This would entail the use of 'virtual prototype technologies', which is an area of study that is lacking in literature. The authors also described the usefulness of visualization in project management. Fumo & Biswas (2015) presented information on linear regression analysis for energy consumption in single-family homes. The energy consumption in residential buildings was observed to be higher.

5.3.4 Energy Survey

In terms of Green House Gas (GHG) systems, Tiwariet et al. (2016) proposed a Photovoltaic Thermal Integrated Greenhouse System (PVTIGS) that could be used to heat a biogas plant within the climatic context of IIT Delhi, India. PVTIGS has various applications, including heat and increased biogas generation. They pointed out that the greenhouse room temperature (38ºC - 47 ºC) was suitable for biogas production. Attar et al. (2013) employed the Transient System Simulation Tool (TRNSYS) to simulate and analyze the performance of Solar Water Heating Systems (SWHS) in a greenhouse based on the Tunisian weather. They observed that additional energy is required to complement that from the SWHS.

Since greenhouses need a certain amount of energy to function, Yildirim & Bilir (2017) chose to use grid-connected solar panels and heat pumps to generate enough energy for lighting. They concluded that it would take 4.9 years in order for the benefits or savings from this setup to accrue. They also reported that for natural gas-based electricity generation, it would take 5.7 years for greenhouse gas emissions to become significant. This is a relatively longer time compared to that for coal-based electricity generation (2.6 years).

6. EXPLORATION OF THE 12 MAJOR WORLD-WIDE RATING SYSTEMS

Exploration was conducted by comparing different worldwide rating systems that are used to evaluate sustainability in buildings. 12 major existing rating systems were identified from the literature review. More specifically, these 12 systems were retrieved from the membership compilation of the World Green Building Council (Fowler & Rauch, 2006). For each rating system, three categories were assessed: economic, environmental and social sustainability. Each category has factors such as energy and Indoor Environmental Quality (IEQ) and an associated level of score used such as (Fail, Pass and Outstanding) and (Certified, Silver and Platinum). For instance, the LEED rating system has eight factors and four levels of the score while CASBEE Japan has two factors and 4 levels of a score.

6.1 Leadership in Energy and Environmental Design (LEED)

Founded in 1998 in the United States, the LEED system for buildings serves as a guideline for rating sustainability (Bernardi et al., 2017). LEED is applicable to both residential and commercial or newer and older buildings. Its accreditation system can be summarized as Certified (40 – 49), Silver (50 – 59), Gold (60 – 79), or Platinum (80+). A new or remodeled building is accredited when it covers the following eight criteria: "Location and Transportation (LT), Supportable Site (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environment Quality (IEQ), Innovation in Outline (ID), and Regional Priority (RP)" (Canada Green Building Council, 2009; Andrade & Bragança, 2010; Berardi, 2015; Ho et al., 2013; Robar, 2018).

6.2 Green Globe

An online rating system, Green Globe provides a framework for sustainability assessment of buildings from its design to its operational phase. It provides information to the public through a system similar to customer reviews for a commercial product. Green Globe is part of Green Building Index (GBI). The American National Standards Institute (ANSI) adopted GBI in 2005, with the first of its merger accreditation standard published in 2010. The Federal Government of Canada is one of the many that employs this rating system (GBI, 2018; & Robar, 2018).

6.3 Green Building Index (GBI)

The Malaysian Institute of Architects (MIA) originally presented GBI in 2009, which is privately used to survey the execution of green structures. GBI contains six appraisal criteria: 1) supportable arranging and administration of rooms, 2) quality of the indoor ecology, 3) energy performance, 4) availability of resources or materials and assets, 5) quality of the indoor environment, and 6) level of sustainability of the organization and management of the building location. GBI uses four fundamental ratings to express sustainability: Certified (50 – 65), Silver (66 – 75), Gold (76 – 85), and Platinum (86 – 100) (Nizarudin et al., 2011; Green Building Index, 2016).

6.4 Green Building Program (GBP)

The Green Building Program (GBP) was developed to enhance energy efficiency performance by raising awareness and improving its recognition in the public sector. An energy review, action and execution plans, and commitment to reporting energy consumption on a regular basis need to be provided by the building management. GBP provides modules that characterize the technical nature of an appropriate committee for each energy service provided by the GBP. Such modules are supplemented by guidelines on relevant issues such as financing, energy audits, and energy management (Green Building Council, 2012; Siemens, 2018; Al-Sakkaf et al., 2019).

6.5 Greenship Indonesia

Indonesia's Green Building Council announced the rating framework, Greenship, in 2010 and 2011. The framework assesses existing structures for: 1) water management, 2) the availability and lifecycle of resources, 3) the building's location, 4) energy performance, 5) indoor environmental quality, and 6) management of the building's environment. Results are embedded into four fundamental evaluations/levels: Bronze (min. of 35%), Silver (min. of 46%), Gold (min. of 57%), and Platinum (min. of 73%) (GBC Indonesia, 2011; GBC Indonesia, 2012; Green Building Council Indonesia, 2018).

6.6 BOMA BESt

Building Owners and Management Association (BOMA) founded an initiative called the Building Environmental Standard (BESt) in 2005. This initiative mainly serves to offer a structure or guideline for the assessment of existing buildings with respect to their management and influence on the environment. This system review three areas: 1) energy and site emissions and water and waste effluents, 2) quality of the indoor environment, and 3) environmental management. Five attainable levels are possible, which include Certified (min. of 59%), Bronze (60-69%), Silver (70-79%), Gold (80-89%) and Platinum (90-100%) (BOMA Canada, 2013; Smiciklas, 2016; Inc., 2013; BOMA Canada, 2011; GBI, 2018).

6.7 German Sustainable Building Council (DGNB)

The DGNB relies on the regular improvements of its baseline certification framework, which makes it one of the crucial frameworks around the world. The DGNB accreditation framework tends to touch on financial matters, ecological, and socio-cultural perspectives. The framework covers all building perspectives through their whole lifecycle, which provides decision-makers with information to characterize their sustainability targets at the planning stage. Furthermore, the DGNB gives a scoring framework covering six criteria and sixty-four subtopics. The accreditation framework given by DGNB involves four levels: Certified (underneath 35), Bronze (35 - 50), Silver (50 - 65), Gold (65 - 80) (Hamedani & Huber, 2012).

6.8 BCA Green Mark Singapore

In 2005, Singapore's BCA Green Mark was established to not only ensure sustainability in new building projects, but also maintain sustainability during and after the accomplishment of the projects. It involves five assessment criteria: 1) water conservation, 2) energy performance, 3) quality of the indoor environment, 4) environmental conservation, and 5) supplementary sustainability criteria. BCA Green Mark applies the following benchmark scheme: Green Mark Certified (50–74), Green Mark Gold (75–84), Green Mark Gold Plus (85–89), and Green Mark Platinum (90+) (BCA, 2012; Ministry of Finance Singapore (MOF), 2016).

6.9 CASBEE Japan

CASBEE, Comprehensive Assessment System for Building Environmental Efficiency, was established in Japan in 2001. It relies on two factors: 1) the quality of the building's environment (both indoor and outdoor), and 2) Load Reduction (LR) of the building's environment (including energy and other resources). In order to attribute an accreditation, the Building and Environment Efficiency Ratio (BEER) is calculated as follows: 1) determine the total score; 2) approximate the final category; and 3) classify into the appropriate level (Naamandadin et al., 2018); (JaGBC, 2008; Baker, 2011; Shamseldin, 2018).

6.10 BREEAM

In the UK in 1990, the Building Research Establishment Environmental Assessment Method (BREEAM) was introduced in order to rate sustainable or environmentally friendly buildings. The benchmark rating system that is employed can be easily calculated. To determine a building's sustainability, BREEAM analyzes ten factors, which contain 50 sub-criteria. The following score levels are possible: Outstanding (above 85), Excellent (70-84), Very Good (55-69), Good (45-54), Pass (30-44) and Unclassified (below 30). Known for its reliable standards, BREEAM assesses nine criteria: pollution, management, energy, transport, water, material, land use, health and wellbeing and ecology. Accreditation is determined according to the 1) calculated ratio, from each criterion, between the attained and attainable points; 2) multiplication of the attained points (in percent) by the weight of each criterion; and 3) addition of all the results from (2) for each criterion. The possible scores are Outstanding (+85%), Excellent (70%-84%), Very Good (55%-69%), Good (45%- 54%), Pass (30%-44%), and Unclassified (below 30%) (Table 4) (BREEAM, 2012; BRE, 2015; & Bernardi et al., 2017).

6.11 HK Beam

The Building Environmental Assessment Method (BEAM) was established in 1996 in Hong Kong as a tool for assessing the sustainability of buildings. It is a modification of the BREEAM and its goal is mainly to enhance the quality and environmental impacts of buildings throughout the period of their existence. It evaluates the existence span of a building and analyzes the quality of the building location, its water and energy consumption, waste generation, quality of the indoor environment, and management and modernization associated with the building. Possible scores include Bronze (equivalent to Above Average or 40%), Silver (equivalent to Good or 55%), Gold (equivalent to Very Good or 65%), and Platinum (equivalent to Excellent or 70%) (Ho et al., 2013; Mahmoud et al., 2019; Al-Sakkaf et al., 2019).

6.12 ITACA

In Italy in 2001, the ITACA system was founded as a nationally accepted accreditation system for environmental sustainability. It is based on the worldwide norm (that is the SB-method) and has, since 2002, been adopted by the International Initiative for Sustainable Built Environment (IISBE). The Italian National Standards Institute UNI recently drafted a document, "*Environmental sustainability in construction tools for the sustainability assessment"*, to enable a building's sustainability assessment. This document incorporates both the ITACA system and other European rating tools (Bragança et al., 2010; Principi et al., 2015; Asdrubali et al., 2015; Al-Sakkaf et al., 2019).

8. CONCLUSION

Through the process of a systematic review, this review paper compiled the top five methodologies applied in SHBs research and identified gaps in major world-wide rating sytems in terms of the indicators that were (or were not) considered. The five methodologies include simulation, Heritage Building Information Modeling (HBIM), visualization, energy survey, and Multi-criteria decision making (MCDM), with HBIM being the most commonly utilized. 12 global rating systems were identified and were described in terms of their rating scales and assessment criteria. These systems did not completely overlap in their list of considered factors and indicators for sustainability assessment. Also, not all of the criteria is applicable to the sustainability assessment of heritage buildings. For all 12 rating systems, there is a difference in the sustainability rating scale, lower limits, and accreditation titles. Since no single rating system could be identified as the most ideal for assessing sustainability in heritage buildings, future research should focus on developing an appropriate rating system that is pertinent to the sustainability assessment of heritage buildings. Using an appropriate research technique, such a rating system can be developed to allow sustainability assessment comparison of heritage buildings around the world.

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