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Research Paper

A comparative study of the methods for establishing a local sustainable building rating system

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ABSTRACT

Sustainable building rating systems (SBRSs) play an important role in promoting the development of sustainable buildings. As SBRSs need to adapt to the local context, many countries and regions have made efforts in recent years to establish their local SBRSs. However, there is no consensus on how to set up a local SBRS. The purpose of this paper is to identify the main steps in and methods for developing a local SBRS and to provide a reference for subsequent research on establishing such a rating system. Therefore, this paper reviews and compares the relevant literature on the regional development of SBRSs. Four main development stages are identified: the selection of indicators and categories, the establishment of a weighting system, conversion into the rating system, and verification and modification. Accordingly, the methods commonly included in the four stages are identified and discussed, and the applicability and limitations of the methods are determined through comparative analysis. Finally, this paper proposes the future research direction related to the establishment of a future SBRS.

1. Introduction

Currently, it is acknowledged that the building and construction sector plays a vital role in promoting sustainable development. The United Nations has reported that the building and construction sector accounts for approximately 40% of global energy use, 12% of freshwater consumption, and 40% of global solid waste generation(The United Nations, 2016). Buildings are also a major source of carbon dioxide (CO_2) emissions, as the building industry accounts for 30% of energy-related greenhouse gas emissions(The United Nations, 2016). In addition to their construction period, buildings continue to impact the environment throughout their life cycle, from the operation and maintenance phase to the process of renovation, refurbishment, and demolition(Mahmoud et al. 2019; Yang et al. 2013).Thus, sustainable building rating systems (SBRSs) have been developed to assess a building's sustainability, including its environmental, social, and economic performance. Currently, there are more than 600 SBRSs worldwide(Kang et al. 2016), including the Leadership in Energy and Environmental Design (LEED) system, the Building Research Establishment Environmental Assessment Method (BREEAM) system, the Comprehensive Assessment System for Built Environment Efficiency (CASBEE), and the international Sustainable Building Tool (SBTool). An SBRS is considered one of the most effective ways to promote the development of sustainable building(Du Plessis and Cole 2011; Lockwood 2006). To describe building environmental assessment techniques, the terms "system", "tool", "method" and "scheme" are often used interchangeably(Cole 2005). A similar situation occurs in regard to "certification", "grading" and "rating". In this

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paper, the term "sustainable building rating system" is used to describe a framework that takes architecture as the evaluation object and that contains a set of building performance criteria with assigned points or weights.

Extensive research has shown that almost all SBRSs were developed to suit a specific country and might not be applicable to other regions(Cole 1998; Haapio and Viitaniemi 2008). A number of environmental and sociocultural factors may affect the assessment attributes and goals, the assessment model and the weighting scheme in each rating system, thus hindering the transfer of SBRSs to other countries or regions; these factors include climate conditions, geographic features, resource consumption, construction materials, government policies and regulations, cultural aspects, and the historical background(Alyami and Rezgui 2012; Crawley and Aho 1999; Krizmane et al. 2016). In recent decades, numerous countries have attempted to create a local SBRS, such as Saudi Araba, Malaysia, and India. However, there is no international consensus on how to establish a new sustainable building assessment method or how to update the criteria, indicators, or weights of an existing system(Li et al. 2017). Meanwhile, in research on sustainable building assessment, many studies have focused on comparing SBRSs from different perspectives, such as the evaluation criteria(Shan and gang Hwang 2018), chronological evolution, strengths and weaknesses(Chew and Das 2008), and scoring methods(Zhang et al. 2019); however, few studies have investigated and compared the methods for developing a local SBRS.

Therefore, the objective of this study is to identify the main stages and methods for developing a local SBRS and to comparatively analyze the advantages and disadvantages of these different methods, which provides suggestions for the future development of a local SBRS. The SBRSs can be classified into two categories: the first one developed by an organization within a country that maintains and manages it, including recognized systems: BREEAM, LEED, CASBEE, etc.; the second one developed by academics but not yet gain widespread adoption in their respective countries. This paper takes the SBRSs in the second category as research objective, because they represent the latest efforts to establish local SBRS and the development process information are easier to obtain.

2. Research methodology

As shown in Figure 1, there are four stages in the process of academic publication selection. First, the literature search was conducted in three academic databases: Scopus, Web of Science and Engineering Village. In this study, the keywords for searching included sustainability, assessment method, development and internationally well-known GB assessment methods (e.g., SBTool, BREEAM), as shown in Table 1. To avoid the omission of any relevant papers, the date range was set to "all years until present" (ending on September 21, 2019). Meanwhile, only journal articles were selected for the review. Conference papers, book reviews, and editorials were eliminated. A total of 455 publications were retrieved.

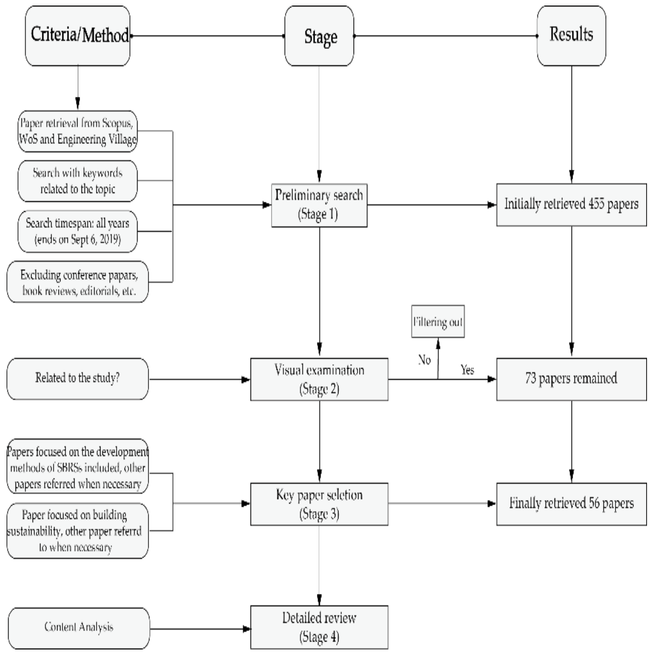

Figure 1. Research framework, modified from(He et al. 2017; Mok et al. 2015)

Table 1. Keywords for searching, modified from(Li et al. 2017)

Search clouds	Sustainability	Assessment method	Development	Specific well-known SBRSs
keywords	green building, sustainable building, ecological building, building environmental performance,	assessment method or system, rating method or system, evaluation, labeling method or system, assessment criteria	developing, establishing, adaptation, adapting, contextualizing, customization	SBTool, GBTool, BREEAM, LEED

However, a large number of these papers merely happened to contain some of the keywords and were not related to this study. Therefore, two rounds of scrutiny were carried out to remove the irrelevant papers, and at the end of each round. The total number of papers after this stage was 73. In the second round, to determine the key papers that exclusively investigated the development methods of SBRSs, a more comprehensive and critical examination was conducted. The criteria for selecting the papers were as follows:

- The study mainly focused on building sustainability assessment. Papers focusing on urban sustainability or landscape sustainability were excluded.
- The study aimed to determine how to develop an SBRS in a specific region, with particular emphasis on the development methods. Papers that only compared different SBRSs rather than developing a new SBRS were excluded.

- The study was published in the English language.

Finally, 56 articles were identified as relevant for subsequent analysis.

3. Results and Discussion

3.1 An overview of the selected publications

Figur presents the trend of the "establishing local sustainable building assessment system" research topic during the 2006-2019 period. As shown in Figur, few papers were published before 2012. However, there has been an enormous upward trend in the number of relevant papers since 2013, indicating increasing interest in this research topic that coincides with the popularity of SBRS research in the past few years(Darko and Chan 2016).

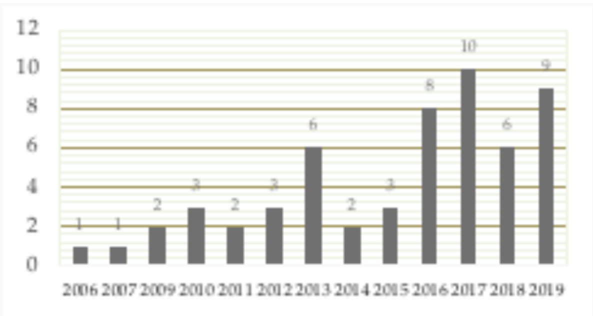

Figure 2. Distribution of publications over time (2019 is an incomplete year)

Table 2. Countries or areas of the SBRSs mentioned in the selected papers

Country/ Region	Frequency
India	7
Portugal	7
Saudi Araba	6
Malaysia	5
Iran	5
China	5
Jordan	3
Hong Kong, China	2

3.2 Represented countries

In general, a selected paper focused on developing an SBRS in one particular country or area. Notably, the country of the authors and institutions may be different from the country of the SBRS. For example, in a study on the establishment of an SBRS in Saudi Araba(Alyami et al. 2013; Alyami and Rezgui 2012), the authors' institution is in the UK. International cooperation is also common in the selected papers. For example, a study on the development of an SBRS for office buildings in Malaysia involves academic institutions in Australia and Malaysia. These two kinds of situations account for 27% of the total number of selected papers, indicating the importance of international cooperation in developing SBRSs.

Table provides a summary of the countries or areas of the SBRSs in the selected papers. As shown in Table, India and Portugal are the leading countries, with each having 7 papers, followed by Saudi Araba, Malaysia, Iran, China and Jordan. Most of the newly developed SBRSs in the selected papers came from Southeast Asia and the Middle East, indicating that these areas have a greater need for developing local SBRSs due to their unique climate conditions. Additionally, the majority of the SBRSs included in the selected papers came from developing countries. This result could be explained by the fact that many developed countries have already built their SBRSs in prior years, such as LEED in the USA, CASBEE in Japan, and BREEAM in the UK. Meanwhile, developing countries might face different barriers to and opportunities in developing their domestic rating methods, as the social and economic infrastructures and the average standard of living are lower than those in developed countries (Malek and Grierson 2016; Todd et al. 2001). It is argued that on the path to sustainability, developing countries should address their basic needs and promote socioeconomic aspects while avoiding negative environmental impacts (Gibberd n.d.).

3.3 Research topics

The development processes and methods of SBRSs in different regions are different due to the various assessment purposes, assessment objects and local contexts. According to the general process of evaluation system establishment, the process of establishing an SBRS is divided into four stages (as shown in Figure 4): the identification of the rating indicators and categories, the establishment of the weighting system, conversion into the rating system, and verification and modification. Notably, the boundaries of these steps are not completely clear due to the complexity of these systems. The following section will analyze the common methods in each stage in detail and discuss their applicability and limitations.

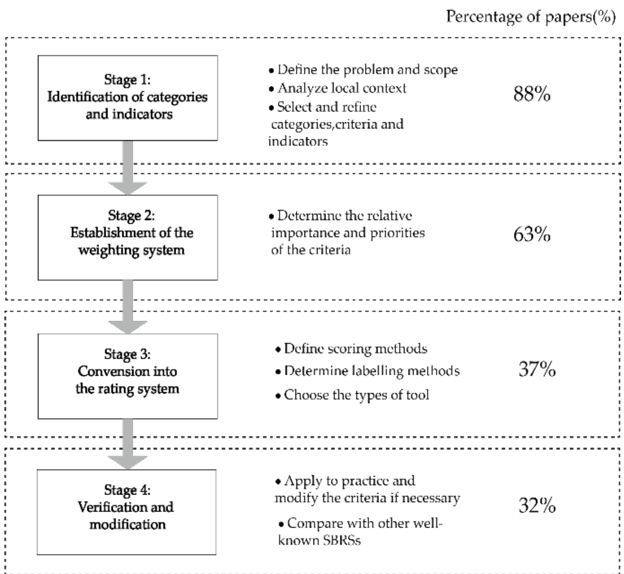

Figure 4. Four stages of developing a local SBRS

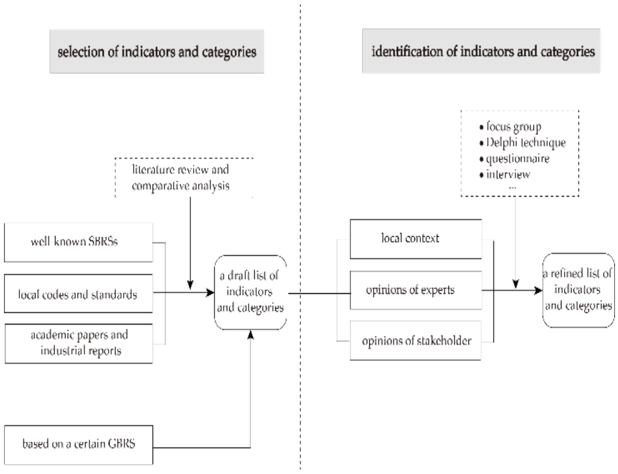

Figure 5. A typical workflow in the selection and identification of indicators and categories

3.3.1 Stage 1: Selection of categories and indicators

The first key step in establishing a local SBRS is identifying the initial sustainable objectives and criteria, including the goal, scope, and indicators. It is necessary to determine the boundary and scope of the assessed object, especially the building types and phases. Among the reviewed publications, 88% deal with choosing the initial criteria and categories (Figure 4).

Error! Reference source not found. shows a typical workflow in this stage. There are two main ways to start developing a local SBRS: the first is based on a well-known SBRS, such as the SBTool and LEED; the second consists of learning from different SBRSs to develop a new one. Among the selected papers, the second way accounts for 90%. This result is in line with the accepted view that comparing previous notable assessment methods is a starting point for establishing new assessment schemes(Cole 2005). By studying the differences between rating systems, it is possible to rectify their disadvantages and to exploit their advantages to develop a new rating system (Shamseldin 2018).

Tables 4 and 5 present a detailed analysis of the quantity and type of SBRSs compared in the selected papers. As shown in Table 2, most studies compared two to six different SBRSs to identify the initial indicators and categories. Only a few studies examined more than seven systems, as the difficulty of comparison increased with the greater number of methods and criteria(Li et al. 2017). Among all the SBRSs, LEED, BREEAM, and CASBEE were the most popular for comparison and analysis, indicating their international influence. In addition, the SBTool, the Green Star, the Hong Kong Building Environmental Assessment Method (HK-BEAM; previously known as BEAM Plus), Green Globes, and the Green Mark were frequently chosen for comparison (Table 4). In the development of a local SBRS, the SBRSs in neighboring countries or regions were also chosen for comparison because they might take into account similar climate and environmental conditions. In addition to SBRSs, academic papers, industrial reports, local codes, and standards are used to make a draft list of indicators and categories.

Table 2. Number of comparative rating systems in each paper (papers that did not mention specific assessment systems are excluded)

Number of assessment systems	Frequency	Percentage
2	3	8%
3	5	13%
4	12	30%
5	6	15%
6	6	15%
7	2	5%
8	1	3%
9	2	5%
10	3	8%

Table 3. The most frequently discussed SBRSs in the selected papers

Assessment system	Nation	frequency
LEED	USA	42
BREEAM	UK	40
CASBEE	Japan	28
SBTool (previously known as the GBTool)	International	17
Green Star	Australia	13
HK-BEAM (previously known as BEAM Plus)	Hong Kong, China	9
Green Globes	Canada	8
Green Mark	Singapore	7
Haute Qualite Environnementale (HQE)	France	6
Green Building Index (GBI)	Malaysia	5
Pearl Rating System (PRS)	United Arab Emirates	5

In terms of methodology, literature reviews and comparative analyses are the most frequently used methods in this stage. In some cases, multiple methods are utilized since the assessed objective is special and few similar rating systems exist as references. For example, in the development of a bamboo-based building sustainability assessment scheme in the Philippines(Salzer et al. 2016), field observations and interviews with stakeholders were conducted to define the criteria. Then, the data were coded and sorted in qualitative content analysis. The criteria were identified and clustered into different dimensions.

As shown in Figure 2, after a draft list of indicators and categories is obtained, it needs to be revised to meet local context requirements. In fact, this step exists in the development of nearly all local SBRSs. However, only 51% of the selected papers discussed the refining process in detail. Table 5 presents an overview of the commonly used methods, including the Delphi approach, focus group discussions, questionnaire surveys and in-depth interviews.

Table 5. Methods frequently used in refining indicators and categories.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Delphi technique			1		1				2	2	6
expert panels							2	1			3
qualitive analysis				1			1				2
interviews				1			1	3	1	1	6
questionnaires	1						1	1	2	1	5
observations				1							1
PCA							1	2			3
focus groups							1		1	1	3
content analysis							1				1
Thurstone Case V									1		1

Among all the methods, the Delphi approach is the most frequently used (Table 5). The Delphi method, which was developed in the 1950s, aims to obtain a reliable consensus from a group of experts(Hsu and Sandford 2007; Okoli and Pawlowski 2004). In the development process of SBRSs, the Delphi approach is an iterative process and usually contains three rounds of questionnaire surveys. This result is in line with previous research in which three rounds of iterations are often enough to collect opinions and to reach a consensus and in which too many rounds might result in expert fatigue and disengagement(Custer et al. 1999; Thangaratinam and Redman 2005). There are many reasons that can explain the widespread use of the Delphi method in developing SBRSs: first, sustainable building assessment criteria are considered multidimensional and require a consensus-based approach(Chew and Das 2008); second, the iterative process allows a deeper understanding and more careful judgment of the research topic among the Delphi panelists; and, third, the participants in a Delphi survey are anonymous, thereby reducing group pressure(Kamaruzzaman et al. 2018). However, as shortcomings of the Delphi method, it is very time consuming and laborious, and it has the potential to result in low response rates(Hsu and Sandford 2007). The differences between the most frequent methods are presented in Table 6.

Table 6. Comparison of the Delphi approach, questionnaire surveys, interviews and focus groups, modified from(Kamaruzzaman et al. 2019; Okoli and Pawlowski 2004)

	Purpose	Procedure	Strength	Weakness
Delphi approach	To obtain a consensus from a group of experts through a series of questionnaire surveys with controlled feedback.	The researchers design a questionnaire and distribute it to the selected group of experts. Then, the researchers analyze the survey results and design another questionnaire, asking the experts to revise their initial responses and/or answer other questions. The researchers repeat this process until a consensus is reached.	1. The iterative process allows a deeper understanding and more careful judgment of the research topic. 2. Due to their anonymity, all participants can form their own judgment independently 3. Free from regional limits: the participants can be contacted by post or e-mail.	1. Time consuming, as more than one round is needed. 2. The potential to obtain a low response rate. 3. Participant commitment is required.
Interviews	To collect information on a particular topic by talking with respondents.	The researchers design the interview outline and then talk with the respondents to collect related information. The researchers need to make interview records through notes or audiotapes.	1. There is a wide range of adaptation, as interviews are applicable with respondents of different ages and educational levels. 2. Strong flexibility. 3. Authentic and detailed information can be obtained.	1. Time consuming and energy consuming. 2. Difficult to record and analyze if an interview is lengthy. 3. Responses might be influenced by the interviewer.
Focus groups	To gather information on and to obtain an in-depth	The research invites and organizes a group of	1. Rapid feedback and results, as multiple	1. Hard to assemble a group of experts.

3.3.2 Establishing a weighting system

As shown in Figure 4, 63% of selected papers deal with Establishing a weighting system. The role of weighting is to express the importance of each indicator relative to the others in a quantitative way(Yang et al. 2010). Developing a parameter weighting system is considered a necessary stage for developing building assessment tools(Ali and Al Nsairat 2009a). It is acknowledged that weighting is the heart of all assessment schemes since it will dominate the overall performance score of the building being assessed(Lee et al. 2002). By giving priorities to different criteria and indicators, the weighting system can be modified to adapt to local conditions, such as climate conditions, materials and the building stock(Banani et al. 2016; Ding 2008).

There are various methods for determining the weights of indicators, and they can be classified into two categories. The first is the objective category, which calculates the weights by the numerical value of each indicator. This category mainly includes principal component analysis, factor analysis, the grey incidence method, the entropy value method, and the rank sum ratio. The second is the subjective category. The decision maker judges the relative importance of indicators based on his/her personal judgment. The subjective category includes the Delphi method, the analytic hierarchy process (AHP), the simple rank order, and ratio weighting(Yang et al. 2010; Yu et al. 2015) As shown in Table7, a consensus-based approach is frequently used in the determination of weights in an SBRS. This result can be explained by the fact that sustainable assessment criteria are considered to be multidimensional(Ding 2008) and inherently complex(Todd et al. 2001). Especially in developing countries, there is no available data source or reference benchmark for sustainable building; thus, the weighting decision inevitably involves subjective judgments. In a consensus-based approach, experts or stakeholders rank various elements in terms of their relative importance, or they assign points to these elements. This ranking or scoring is then used to establish the weights.

Table 7. Frequently used weighting methods in the selected papers

	AHP	combination of the AHP and other methods		other methods	
	frequency	frequency	specific methods	frequency	specific methods
2006	0	0		1	indicate suggested weighting
2007	1	0		0	
2009	1	0		0	
2010	2	0		0	
2011	1	0		0	
2012	0	0		1	direct ranking
2013	1	1	AHP+direct ranking	1	Delphi ranking
2014	1	0		0	
2015	2	0		0	
2016	3	2	breakdown method and compensation technique+AHP; fuzzy-Delphi-AHP(FD-AHP)	1	severity index (SI)+exploratory factor analysis
2017	3	2	AHP+direct ranking; AHP+ weighted harmonic mean+Shannon's entropy	2	qualitive analysis, relative importance index (RII)
2018	3	1	Fuzzy- AHP	1	DANP (the results of DEMATEL and concepts of the ANP)
2019	0	3	AHP+RII (relative importance index); AHP+relative significance index (RSI); fuzzy AHP; AHP+fuzzy integrals	2	fuzzy TOPSIS

Among all the weighting methods, the AHP is the most frequently used method for establishing the weighting system of indicators (Table 7). Developed by Thomas L. Saaty in 1980, the AHP is a multicriteria decision-making (MCDM) method and is widely used to determine the shared opinion of a group. The AHP utilizes a multilevel structure to organize various factors in complex problems, and it simplifies the decision-making process into pairwise comparisons for experts(Markelj et al. 2014). In addition, the AHP can minimize the common problems with team decision-making processes, such as a lack of focus, planning, participation or ownership, which ultimately are costly distractions that can prevent teams from making the right choice(Ali and Al Nsairat 2009b).

As shown in Table 7, there is a tendency to combine the AHP and various methods to determine the weighting, such as the fuzzy- AHP(Zarghami et al. 2018, 2019), the Delphi- AHP(Kamaruzzaman et al. 2018), the fuzzy-Delphi analytic hierarchy process (FD-AHP)(Kang et al. 2016), AHP+ the weighted harmonic mean + Shannon's entropy(Aboul-Zahab et al. 2015), the AHP+ the relative importance index (RII)(Shari and Soebarto 2017), and the AHP+ the relative significance index (RSI)(Wu et al. 2019). This tendency can be explained by the complexity and multidimensional nature of sustainable building assessment schemes. Such schemes involve environmental, social, and economic issues, and therefore, the process of establishing the weighting system for sustainable indicators should be comprehensive and flexible(Ali and Al Nsairat 2009a; Alyami et al. 2015; Ding 2008). This process should utilize different integrated methodologies by exploiting the advantages and bypassing the disadvantages of each method to establish a new compatible method. In addition to AHP methods, in recent years, more MCDM methods have been adopted in developing local SBRSs, such as the fuzzy Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) and the Decision-Making Trial and Evaluation Laboratory and Analytical Network Process (DANP). Table 8 summarizes the differences between these widely used methods and provides an overview of the advantages and disadvantages of each method to enable comparison and selection.

Table 8. Comparison among the most frequently used weighting methods

	Purpose	Procedure	Strength	Weakness	Reference
AHP	Saaty (1980) developed an MCDM method called the AHP for complex multicriteria problems including qualitative judgments. This method is based on three main principles of decomposition, comparative judgment, and synthesis of priorities.	1. Defining the research problem and objectives. 2. Establishing a hierarchical structure. 3. Formulating judgment matrices for pairwise comparison. 4. Checking the consistency of the outcomes. 5. Determining the weight of each assessment aspect.	1. The AHP can reduce complex decisions to a series of one-to-one comparisons. 2. The hierarchical structure can easily be adjusted to fit multifaceted problems. 3. The AHP helps in reducing bias in decision-making, and it can minimize common pitfalls of team decision-making processes. 4. Checking the consistency of the outcomes.	1. As the final percentage weights are not known to the respondents, experts are unable to rectify any anomalies that may arise. 2. There may be inconsistent judgments due to the limitations of the human mind when dealing with numerous factors at the same time.	(Chandratilake and Dias 2013; Lee 2014; Wu et al. 2019)
Fuzzy AHP	Buckley (1985) incorporated a fuzzy matrix into the AHP method, so that vagueness in the responses of the people involved in decision-making can become integrated, get closer to human reality and provide decision-making analysis with more validity.	1. A fuzzy evaluation matrix is developed. 2. The calculation of the possibility degree between two triangular fuzzy numbers is performed. 3. The degree of possibility of convex fuzzy numbers is found. 4. Normalized weight vectors are calculated, and the final weight of an individual category and criterion is determined.	The drawbacks caused by the ambiguous and uncertain nature of human judgments can be resolved, and therefore, the results will be more reliable and truthful.		(Zarghami et al. 2018, 2019)
Fuzzy TOPSIS	Fuzzy TOPSIS is used to select the best alternative or to rank a group of alternatives that have different criteria and attributes.	1. Linguistic responses are converted into fuzzy numbers. 2. A weighted normalized decision matrix is computed and found. 3. The fuzzy positive ideal solution (FPIS)	In several studies, it has been proven that this technique is capable of overcoming the uncertainties that arise when considering the opinions of individuals in the weight determination process and that it	In the TOPSIS model, it is difficult to weight and to maintain the consistency of judgments.	(Bansal et al. 2019; Mahmoud et al. 2019)

3.3.3 Conversion into the rating system

After the establishment of the weighting system, the relative importance of the categories and indicators is determined. There is a conversion process between this initial assessment framework and the rating system, including the determination of the scoring method, the labeling method, and the type of tool.

- **Scoring method**

A previous study suggested that a green building rating tool (GBRT) consists of an indicator system and a quantitative evaluation system (QES), while the QES consists of three subsystems: the rating subsystem (RS), the scoring conversion subsystem (SCS), and the scoring subsystem of terminal indicators (SSTI) (Zhang et al. 2019). In other words, to obtain the final rating result, three scoring methods need to be defined: how to score terminal indicators, how to score each category, and how to calculate final scores.

The terminal indicators are usually assessed on a three-to-six-tier scale depending on how much demand they meet (e.g., not achieved=0, partially achieved= 0.5, achieved=1). There are two kinds of indicators: those that are quantitively and qualitatively assessed. Certain criteria are measured quantitatively based on a quick calculation with the help of certain software tools that are freely available. For the criteria that are assessed qualitatively, the score is determined based on the user's own estimation of the fulfillment of demands.

There are three main scoring methods at the level of the category and the total result: Simple additive weighting (SAW) method and direct additive method. In recent years, fuzzy logic tools have been introduced in developing the scoring scheme in some cases, such as in developing sustainable commercial building assessments in India. Fuzzy logic tools help to quantify qualitative criteria and allow users to include the unavoidable imprecision due to the lack of available information(Bhatt and Macwan 2016).

The scoring method is closely related to the weighting method. Any of the scoring methods above can be combined in a rating system as well.

- **Labeling method**

Table 9 shows the hierarchy of the SBRSs in the selected papers. Most of the SBRSs use a labeling system with a four-level hierarchy. This result is in line with a previous study on the prevailing SBRSs[17]. The underlying rationale might be that using a hierarchical system with a large number of levels can induce building owners to continue upgrading their existing buildings or to construct their new buildings that have a higher level of sustainability, which can result in a constant improvement in the development of a sustainable built environment. The types of popular labels include the number of stars (one-star, two-star, etc.), the type of metal (copper, silver, gold, etc.) and the level of greenness (not green, good, excellent, outstanding, etc.). The type of labeling system adopted is usually determined by the consensus of experts and the public. In this process, questionnaire surveys, expert panels, and reviews of widely used tools are commonly used methods.

Table 9. Number of comparative assessment systems in each paper

The hierarchy of the rating result	Frequency
3 (e.g., one-star, two-star, three-star)	3
4 (e.g., not green, good, excellent, outstanding)	7
5 (e.g., certified, bronze, silver, gold, platinum)	3
6 (e.g., failing, passing, good, very good, excellent, outstanding)	4

- **Types of tools**

When an SBRS is applied in practice, it needs to be transformed into tools that take different forms, such as checklists and software. Table 10 summarizes the differences between these forms and provides an overview of the strengths and weaknesses of each form to enable comparison and selection.

Table 10. Comparison among checklists, guidelines and computer programs, source:

	Characteristic	Strength	Weakness	Reference
Checklist	Includes the basic assessment criteria and categories for a quick check in the form of a table or list.	1. Relatively quick and easy to complete for the user. 2. Permits comparisons between buildings of very different types.	Difficult to obtain an accurate rating result.	(Gething and Bordass 2006)
Guideline	Includes requirements or guidance in the design and construction of sustainable buildings, such as design principles, detailed strategies, and available technologies.	1. Supports the decision-making process in the building design, construction, operation and modeling phases. 2. Lucid and user-friend.	Lacks flexibility in customization to suit specific conditions.	(Chew and Das 2008; Han and Kim 2014)
Computer program	After inputting parameters in the computer software, the rating result is quickly presented.	1. User-friendly and easy to operate. 2. The results are often presented in the form of images, which are easy to understand and compare.	The transformation of information from building model software to the rating software may be a problem.	(Vyas et al. 2019)

3.3.4 Verification and modification

The last stage of establishing an SBRS is verification and modification. In this stage, the adaptability, feasibility, and effectiveness of the rating system need to be verified, and feedback is obtained to revise the system. Among the reviewed publications, 32% deal with verification and modification.

As shown in Table 10, the case study is the most commonly used method for validating a proposed rating system. The proposed rating system is applied to real projects or building simulations. In this process, the usability of the criteria, weights and scoring method is checked, forming the basis for further refinement. The number of buildings chosen for a case study varies from 1 to 48 according to the goal and scope of the rating system. Most studies select one to three typical buildings, especially certified buildings and green demonstration projects, to verify the proposed scheme, as these buildings are representative and provide a reference for the establishment of the benchmark. Some studies choose more buildings, covering different typologies or building scales, to check the widespread use of the rating system.

In this stage, a comparative analysis between the proposed rating system and a well-known SBRS is the second most frequently used method in the selected papers. Similar to the result in 3.3.1, LEED, CASBEE, BREEAM, and the SBTool are commonly chosen for comparison. Different aspects of the rating systems and the proposed scheme are compared and analyzed, including the performance sensitivity, criteria, weighting, certification levels, and scoring method. By discussing the similarities and differences between the proposed rating scheme and other well-known tools, the priorities and characteristics of the proposed rating system are presented and can be verified in further study. In addition, through comparative analysis, most studies prove the necessity of developing a rating system adapted to a specific country, as differences are often related to the local contexts, such as climate, culture, and social and economic aspects.

Other methods, including focus groups and in-depth interviews (e.g., questionnaires), are used to obtain the opinions of experts or users on the proposed rating system.

Table 11. Methods used in stage 5 in the selected papers

Method	Frequency
Case studies	11
Comparative analysis among SBRSs	6
In-depth interviews	1
Focus groups	1
Total	19

4. Conclusion and recommendations

An SBRS is a vital driving force in promoting the sustainable development of the construction industry. Meanwhile, only a regionally appropriate rating system can reasonably evaluate the performance of different aspects of buildings. Therefore, a local rating system can improve the economic and social benefits of buildings while reducing the negative impact on the environment. In addition, a local rating system encourages architects, engineers, and other industry practitioners to rethink sustainable design, and it also improves public awareness of sustainability.

The present research aimed to identify and compare the methods used in developing local SBRSs. Four stages of development of local SBRSs were identified: (1) the identification of indicators and categories; (2) the establishment of the weighting system; (3) the formulation of the rating system; and (4) verification and modification. Most studies focused on the identification of indicators and categories, while little research focused on the verification and modification of SBRSs.

The main methods used in each stage are listed in Figure 6. In stage 1, the comparison of widely recognized SBRSs is usually the starting point for establishing a local SBRS. Other materials, such as academic papers, local standards, and codes, are also reviewed to identify the initial indicators and local contexts. The Delphi technique and expert panels are often used to obtain opinions from experts and stakeholders. In stage 2, the AHP is the most frequently used weighting method. Due to the limitations of the AHP method, there is a tendency to combine the AHP and various methods to determine the weighting scheme, such as the fuzzy AHP, the Delphi- AHP, and the AHP-RII. In stage 3, the main scoring methods include SAW, the direct additive method, and fuzzy logic tools. The labeling method and rating tool type are also decided in this stage through comparative analysis with other SBRSs or interviews with experts and stakeholders. In stage 4, the main methods for verifying the proposed SBRS are case studies and comparative analysis between the proposed rating system and well-known SBRSs.

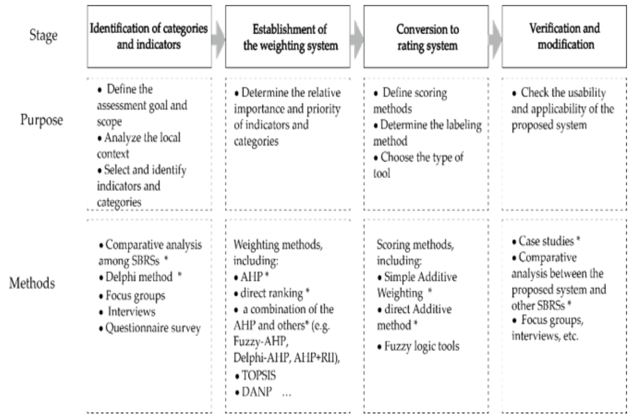

Figure 6. A summary of the main methods in each stage; frequently used methods are marked with *

Due to the complexity and multidimensional nature of sustainable building assessment, the boundaries of the above stages might be vague, and combining various methods to develop an SBRS could be productive and beneficial.

This study suggests the following areas for further research in relation to the development of a local SBRS:

- Select the path to develop a local SBRS. As mentioned above, there are two main approaches: the first is based on an international rating system (such as the SBTool), adjusting the weighting according to the local context; the second involves benefiting from a variety of widely recognized SBRSs to build a local rating system. These two paths require further study to identify their advantages and disadvantages.
- Maintain the balance between the complexity and accuracy of the development methods for SBRSs. To obtain more accurate results, more decision-making methods and statistical methods are introduced to develop SBRSs. However, a complicated method is not necessarily a better method, as complexity might increase the difficulty of use and dissemination.
- In the process of building an SBRS, the opinions of different stakeholders should be absorbed. In addition to experts in the field of sustainable building, the views of construction industry professionals, government officials, and the public need to be taken into account. At the same time, different stakeholders might have different understandings and knowledge of sustainability issues. Therefore, it is necessary to study how to incorporate and determine the importance of different opinions from stakeholders in the development of SBRSs.
- Strengthen research on the verification and modification of SBRSs. The most widely accepted

SBRSs are usually revised every two or three years. As mentioned above, there are few studies on the verification and modification of rating systems at the regional level. Therefore, it is necessary to study how to establish corresponding schemes or processes to dynamically adjust SBRSs.

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