A systematic review of the international assessment systems for urban sustainability

Pedro J³, Reis A³, Duarte Pinheiro M², Silva C³

1 IN+Center for Innovation, Technology and Policy Research, Instituto Superior Técnico – Universidade de Lisboa, Avenida Rovisco Pais 1, 1049-001, Lisbon, Portugal
2 Department of Civil Engineering, Architecture and Georesources, Instituto Superior Técnico – Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001, Lisbon, Portugal
joana.m.pedro@tecnico.ulisboa.pt

Abstract. Planning and managing the rapidly growing cities in a manner that delivers a balanced solution for their environmental, social and economic long-term development constitutes one of the grand challenges of societies. In the urban planning field, several sustainability assessment systems emerged to guide the planning process towards these goals. After two decades of existence, there is a need to further analyze the lessons learned from the application of these systems and discuss the pathways towards more sustainable societies. This paper provides a literature review of the most widely used urban sustainability assessment systems: BREEAM Communities, LEED Neighborhoods, CASBEE Urban Development, Green Star Communities, and DGNB Urban Districts. Here, we analyzed 124 publications on the topic published between 2015-2018, using the selected assessment systems as keywords. This study revealed that there is a need for context customization of global targets into local actionable measures; involvement of regulatory bodies to ensure the successful application of such systems; and, consideration of socioeconomic factors as the assessment is still very focused on the environmental impact. This study provides insights for practitioners and researchers on the existing systems to assess urban sustainability and pathways for future research.

1 Introduction

The share of the global population that lives in cities has been growing and is projected to rise to 68% by 2050 [1]. While cities are hubs of development, they also pose increased stress in the demand for scarce resources and environmental concerns, which affects the economic and social balance of urban areas. These concerns rise the need for systems that can enable sustainable planning for managing the rapid growth of cities in a long-term perspective [2], [3].

As a response to these concerns, the construction industry has been making efforts to integrate sustainability principles into projects planning and practices by developing sustainability assessment systems like BREEAM (UK, 1990), LEED (USA, 1998), CASBEE (Japan, 2001), GREEN STAR (Australia, 2002) or DGNB (Germany, 2008), used and recognized internationally [4], [5]. These systems provide a set of indicators to evaluate the sustainability performance of a building, which can help the project owner to manage the impacts of their construction project [6]. Although the number of indicators and metrics may differ, they all define a set of criteria to assess a construction project based on their environmental, social and economic dimensions [6],[7],[8],[9]. In the last decade, these systems have also new versions for neighborhood sustainability assessment (NSA), such as BREEAM Communities, LEED Neighborhoods, CASBEE Urban Development, DGNB Urban Districts. At the neighborhood scale, buildings become a component of an urban system, interrelated with the other components, such as public transport, and services. At this scale, it is also possible to explore to its fullest the synergies among buildings and its surroundings, for instance, by making use of district energy solutions and taking advantage of economies of scale. However, it also introduces complexity in the evaluation process, with a higher number of stakeholders involved, and the increased number of indicators [4], [5], [10], [11]. Moreover, there are still few certified neighborhood projects compared to the building scale. For instance, sustainable assessment systems, such as BREEAM passed already the 400,000 building certificates [12], but only summed 50 neighborhood projects by 2018 [13], followed by LEED system with over 100,000 certified buildings and only 188 neighborhood projects [14].
Previous research has largely discussed the metrics for evaluating sustainability at the building scale, for which more mature assessment systems exist for a longer time, but relatively few studies have focused on the urban scale [15]. Happio [16] was one of the first studies to provide a critical review of the main categories used by three of the most well-known NSA systems (BREEAM-Communities, LEED-Neighborhood development, and CASBEE-urban development) and highlighted the potential problems of using these systems outside its region of the origin. In this line, Sharifi & Murayama [8], [17] conducted an in-depth analysis of seven NSA systems, introducing a framework for the examination of NSA systems, and discussing some of their common limitations. Regarding the categories used to measure sustainability, Komeily & Srinivasan [18] criticized the systems for underperforming in the social, economic, and institutional aspects of sustainability. Tam et al. [19] contributed with an extended review of the NSA systems, evaluating 20 international systems and comparing their different approaches on urban sustainability, similarities, and limitations. While previous review studies contain implicit or explicit knowledge of the NSA limitations and research gaps, no prior study, to the best of our knowledge, has applied a systematic review approach to identify the main shortcoming of the existing systems for assessing urban areas.

In this study, we selected five of the most widely spread NSA systems for an in-depth analysis: LEED Neighborhood Development, BREEAM Communities, DGNB Urban Districts, CASBEE Urban Development, GREENSTAR Communities [20] [19]. These five systems were chosen because they are well developed and known internationally, have the highest number of certified projects, have publicly available manuals, and include scoring as part of their process. Here, we browsed the existing publications on the topic based on the name of each system as a keyword. The analysis is limited to the publications between 2015-2018 in peer-reviewed articles in the urban planning field, which resulted in the identification of 124 publications. Afterward, we made an in-depth analysis of the gaps and limitations of these systems for future improvement. This framework can be a starting point for researchers to formulate new assessment systems or improving the existing ones.

This paper is structured as follows. Section 2 describes the analytical framework used for identifying the gaps in the literature. Section 3 presents and discusses the results of the gap analysis. Finally, Section 4 summarizes the main conclusions of this analysis and identifies future research avenues.

2 Methodology

This study started with a comparison of each system based on the statistics and content analysis from their technical manuals. This process focused on the analysis of their similarities and differences in terms of timeline, spatial spread, categories, and certification. Even though each NSA system aims at measuring and attaining sustainability in urban areas by providing a set of criteria and weights, the organization of these criteria tends to be different, making it difficult to compare the systems. To overcome this challenge, we rearranged the issues and indicators of the NSA systems in a common framework, grouping the criteria under the three main sustainability dimensions: environmental, social and economic. We proceeded with the review of the published scientific literature concerning the NSA systems to identify the gaps most frequently mentioned. This review followed the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [21] [22] [23]. We started with a search in Web of Science and Scopus of the following by keywords: “Neighborhood Sustainability Assessment”; “LEED neighborhoods” or “LEED-ND”; “BREEAM communities” or “BREEAM-CM”; “CASBEE urban development” or “CASBEE-UD”; “DGNB urban districts” or “DGNB-UD”, and “Green Star Communities” or “Green Star-CM”. With this approach, we identified 821 records, of which 275 duplicated were removed. Then, we restricted the data to peer-reviewed articles written in English and published between 2015-2018, and to literature that focused on the urban scale rather than buildings. This resulted in the selection of relevant 124 articles for further systematic review and identification of the most frequent gaps of the NSA tools.
3 Results and discussion

3.1 Comparison of the NSA systems.

This section presents the comparison of the analyzed NSA systems regarding their timeline, spatial spread, categories and scoring (summarized in Figure 1, Figure 2, Table 1).

BREEAM was the first developed system. Its first version for the building scale was launched by the UK Building Research Establishment in 1990, and BREEAM Communities (BREEAM-CM) version for urban planning was released in 2012 [24]. BREEAM-CM provides a set of criteria to evaluate sustainability distributed within five main categories: governance, social & economic wellbeing, resources, land use and ecology, and transport and movement. It also provides bonus credits for innovative features. Distributed under these categories, there are 40 criteria, subjects to scoring, of which 12 are mandatory. By fulfilling the criteria, projects earn points that determine its certification level: Pass (30 points), Good (45 points), Very Good (55 points), Excellent (70 points) and Outstanding (80 points) [24]. In 2018, there were 50 BREEAM-CM certified projects, 45 in Europe and 5 in Asia [25].

LEED was launched by the U.S. Green Building Council in 1987, and LEED Neighborhoods (LEED-ND) version was released in 2014 [26]. LEED-ND evaluates sustainability performance at the urban scale by addressing three main categories: smart location and linkage, neighborhood pattern and design, and green infrastructure and buildings. It also accounts for two extra categories: innovation; and regional priority. Distributed under these categories, there are 40 credits subjects to scoring and 12 prerequisites that must be respected but do not count for scoring. By fulfilling credits, projects earn points that determine its certification level: Certified (40 points), Silver (50 points), Gold (60 points) and Platinum (80 points) [26]. In 2018, there were 188 certified LEED-ND projects, 145 are in North America, 35 in Asia, 4 in Europe, 3 in South America, and 1 in Africa [27].

CASBEE was launched by the Japan Sustainable Building Consortium (JSBC) in 2001, and CASBEE Urban Districts (CASBEE-UD) was released in 2006 [28]. It considers the improvement of three main urban dimensions: environment, society, and economy. The evaluation attributes a score to each of these dimensions based on two factors: built environment quality (Q) and built environmental load (LR), the assessment scale for Q and LR ranges from 1 to 5. Then, these two factors are used to calculate the final score for Built Environment Efficiency (BEE). For CASBEE-UD there are no mandatory requirements. The calculated score projects determine its certification level: Poor (BEE 0.5), Fairly Poor (BEE 0.5-1), Good (BEE 1-1.5), Very good (BEE 1.5-3), and Excellent (BEE 3) [28]. In 2018, there were 5 CASBEE-UD projects, all of them in Asia [29].

DGNB was first developed for the building scale in 2008, and DGNB Urban Districts (DGNB-UD)
was released in 2012 [30]. DGNB-UD includes the five main categories of assessment: environmental quality, economic quality, sociocultural and functional quality, technical quality, and process quality. Distributed under these categories, there are 30 criteria subjects to scoring. By fulfilling credits, projects are given credits for their performance in the different categories. In LEED-ND, the weights are more evenly distributed, with 11% attributed to each of the six categories. In CASBEE-UD, the weights are more heavily concentrated in the environmental and social dimensions, with 12% given for each.

Green Star was launched by the Green Building Council of Australia (GBCA) in 2002, and Green Star -Communities (Green Star-CM) was released in 2012 [32]. The evaluation process comprises the collection of credits for four main categories: governability, livability, economic prosperity, and environment. It also provides bonus credits for innovative features. Distributed under these categories, there are 32 credits subjects to scoring. By fulfilling credits, projects earn points that determine their certification level: Silver (45 points), Gold (60 points), Platinum (75 points). In 2018, there were 40 certified Green Star-CM projects, all in Australia [33].

Overall, although the number of indicators and metrics may differ between systems, they all define a set of criteria to assess a construction project based on their environmental, social, and economic dimension, as summarized in Table 1. This analysis shows that BREEAM-CM, LEED-ND, and DGNB-UD present a higher number of criteria and weight related to access to services, but attribute a much lower number of criteria and weights to cultural heritage and life cycle costs. In fact, BREEAM-CM, LEED-ND systems address only indirectly life cycle costs by incorporating it in the energy's evaluation measures and reuse of materials. In CASBEE-UD the weights are more evenly distributed, attributing slyly higher importance to waste, land use, participation, and governance, but there is no specific category for life cycle costs. Finally, GREEN STAR-CM also attributes higher importance to participation and governance, but less importance to cultural heritage. Overall, the NSA tools have more criteria and attribute more weight to the environmental and social dimensions of the evaluation, rather than the economic factors.

| Table 1 - NSA tools: criteria and weight comparison |
|--------------------------------------------------|
| BREEAM-CM | LEED-ND | DGNB-UD | CASBEE-UD | GSTAR-CM |
| **Environmental criteria** | **Energy** | minimum building energy performance; solar orientation; optimize building energy; renewable energy; district heating and cooling; infrastructure energy efficiency (Wt: 9%) | energy infrastructure; LCA -emissions (Wt: 9%) | possibility demand/supply ...; adaptability and expandability (Wt: 6%) | greenhouse gas strategy; peak electricity demand (Wt: 8%) |
| **Water** | water strategy; water pollution; rainwater harvesting (Wt: 5%) | indoor water use reduction; wastewater management (Wt: 5%) | water resource – waterworks; sewerage (Wt: 6%) | integrated water cycle (Wt: 7%) |
| **Waste** | low impact materials; resource efficiency; existing buildings; sustainable buildings (Wt: 12%) | construction activity | waste diversion; recycling and reused infrastructure (Wt: 8%) | waste/resource conservation, waste resilience and adaptability; resource management (Wt: 10%) | resources recycling; construction; operation; environmentally considerate buildings (Wt: 17%) |
| **Land use** | ecology strategy; enhancement of ecological value; green infrastructure; land use; landscape (Wt: 12%) | smart location; imperiled species; wetland & water body conservation; agricultural land conservation; site design for habitat or wetland; restoration of habitat or wetlands; long-term conservation management; minimized site disturbance (Wt: 4%) | biodiversity; land use; smart infrastructure; land use efficiency (Wt: 15%) | greenery - ground greening; building topography; reforestation; ecological value (Wt: 4%) | sustainable sites; ecological value (Wt: 4%) |
| **Noise pollution; light pollution** | light pollution reduction (Wt: 5%) | thermal comfort: open spaces; open space; noise, exhaust and light emissions (Wt: 10%) | view; inhabitant population; staying population; (Wt: 8%) | healthy and active living; light pollution (Wt: 6%) |
| **Adapting to climate change; flood risk assessment; flood management; microclimate** | rainfall management; floodplain avoidance; steep slope protection; brownfield remediation; heat island relief (Wt: 8%) | urban climate; environmental risks; groundwater and soil protection (Wt: 7%) | basic disaster prevention; disaster response ability; traffic safety; crime prevention (Wt: 11%) | adaptation and resilience; safe places; heat island effect (Wt: 7%) |
### Access to services
- Access to public transport
- Public transport facilities
- Transportation assessment
- Preferred locations
- Access to quality transit
- Motorized transportation
- Pedestrian and cyclist facilities
- Convenience
- Health and welfare
- Education
- Development of traffic facilities
- Access to civic & public space
- Traffic logistics management
- Access to amenities
- Access to fresh food
- Sustainable transport & movement

### Local vernacular
- Historic resource preservation
- Community outreach and involvement
- Integrated design
- Consultation plan
- Green star accredited professional

### Urban design
- Urban design
- History and culture
- Culture, heritage and identity
- Consultation and engagement
- Design review
- Training and skills
- Community management of facilities
- Integrated design
- Consultation; project management; governance; monitoring
- Compliance; area management; information service performance; information system - block management
- Community participation & governance

### Heritage
- Local vernacular
- Historic resource preservation
- Community outreach and involvement

### Economic impact
- Housing and jobs proximity
- Value stability
- Local economic impact
- Economic development - revitalization activity
- Economic development - revitalization activity
- Economic development - revitalization activity
- Economic development - revitalization activity
- Economic development - revitalization activity
- Economic development - revitalization activity

### Economic prosperity
- Life cycle cost
- Life cycle cost
- Life cycle cost
- Life cycle cost
- Life cycle cost

### Life cycle
- Not found any exclusively dedicated criteria, although costs calculation is included in the energy-related criteria
- Life cycle cost; partially included in resilience and adaptability
- Return on investment

### Social criteria
| Social criteria | Access to services | Local vernacular | Urban design | History and culture | Culture, heritage and identity |
|-----------------|--------------------|------------------|-------------|---------------------|-----------------------------|
| Access to public transport; public transport facilities; transport assessment; cycling network; cycling facilities; local parking; demographic needs; delivery of services; facilities; public realm; utilities; inclusive design; safe and appealing streets | preferred locations; access to quality transit; transit facilities; transportation demand management; bicycle facilities; reduced parking footprint; compact development; connected and open community; mixed-use neighbor; access to civic & public space; access to recreation facilities; neighbor. schools; walkable streets; local food production; visibility and universal design; tree-lined & shaded streets | local vernacular (Wst: 1%) | urban design (Wst: 3%) | history and culture (Wst: 3%) | culture, heritage and identity (Wst: 3%) |

### Identified shortcomings
1. Lack of consensus on sustainability definition and concepts
2. Overlapping and incoherent distribution of criteria and weighting
3. Need for widening the scope by including evaluation criteria on socioeconomic conditions, mobility and walkability, disaster resilience and climate change, cultural factors
4. Little flexibility for local adaptation, particularly for developing countries
5. Need to adapt the assessment systems for urban regeneration projects
6. Regulatory bodies involvement and participation
7. Need for widening the scale of assessment
8. Integration of the NSA with computer-based models

### Table 2 - NSA systems: results from the gap analysis

| Gaps identified | % of Papers |
|-----------------|-------------|
| G1 Lack of consensus on sustainability definition and concepts | 10% |
| G2 Overlapping and incoherent distribution of criteria and weighting | 18% |
| G3 Need for widening the scope by including evaluation criteria on socioeconomic conditions, mobility and walkability, disaster resilience and climate change, cultural factors | 26% |
| G4 Little flexibility for local adaptation, particularly for developing countries | 28% |
| G5 Need to adapt the assessment systems for urban regeneration projects | 11% |
| G6 Regulatory bodies involvement and participation | 18% |
| G7 Need for widening the scale of assessment | 9% |
| G8 Integration of the NSA with computer-based models | 6% |

*total number of papers analyzed: 124
G1 - Lack of consensus on sustainability definition and concepts. Results from the literature review show that sustainability is not a fixed term yet [34], [19]. One of the first definitions of sustainable development was set by the Brundtland Commission 1997 [35], that emphasized that sustainable development is only achievable through the integration and acknowledgment of economic, environmental, and social concerns throughout the decision-making process. These concerns became the main pillars for most of the NSA systems, which investigate practical ways of measuring and achieving the sustainable development of urban areas [19], [34], [36] [37] [38]. As argued by Boyle [7], although NSA systems address the concept of urban sustainability by providing a practical pathway to measure it based on a set of indicators, they often group and use different metrics and weights to each sustainability issue. In this sense, further consensus on the concepts and definition is necessary to make them globally applicable and understood.

G2 - Overlapping and incoherent distribution of criteria and weighting. Because of the lack of consensus on the definition of sustainability, these systems often face the problem of completeness, and overlapping criteria [39]. Reihl [39] further highlights that the lack of a consensual definition and clear metrics makes it difficult to measure the sustainable performance of a project and makes the comparison of the different rating systems ambiguous, as it is not possible to make a direct correlation between categories or translation between their overall scores. For instance, a high score achieved by a project in the BREEAM-CM does not immediately translate into LEED-ND high performance, which raises the question about what exactly do they measure (“Do green neighborhood ratings cover sustainability?”). Wallhagen [40] argues that the use of interchangeable criteria can create a bias in the analysis because if the sustainability aspects are exchangeable, a project can become certified without being sustainable. Also, Komeily [18] and Kaur [22] argue that there is a need for a more coherent distribution of the criteria and categories. Ali-Toudert [15] argues that these systems have often overlapping criteria, and often ignore interactions between the criteria, which may lead to the overestimation or underestimation of sustainability compliance.

G3 - Need for widening the scope. Although the efforts of NSA systems to provide a holistic approach towards sustainability, the literature review revealed that most of these systems lack completeness in terms of content and criteria. Authors such as Wu [41], [42] notice that these systems emphases on the ecological and environmental aspects, ignoring the economic and social aspects of sustainability. Gouda [43] and Riggs [44] discuss the criteria used to evaluate the mobility modes and point out the need for a more expansive view of walkability based on both quantitative and qualitative factors. Sally Naij [45] and Diaz-Sarachaga [46] notice the need to include evaluation criteria for climate change adaptation and disaster resilience. Kaur [22] highlights that the evaluation often attributes more importance to certain aspects like infrastructure and resource management rather than cultural, business and innovation.

G4 - Little flexibility for local adaptation. Most of the NSA systems are developed within a certain country but are often used in contexts other than their origin. This opens the debate on the viability of using global standards and the pertinence of their use in actual local conditions [47] [48]. In this context, Gouda [49] further highlights that NSA systems are often related to standards, codes, guidelines highly dependent on the country of origin, which is contradictory to their characterization as independent or international. Kaur [22] argues the need to assure local requirements and site-specific aspects which may differ within cities and regions. Authors such as Dawodu [50] Diaz-Sarachaga [51] also point out that most of the existing NSA systems come from developed countries, particularly North America and Europe. Yet the developing countries such as African cities, are the ones expected to have the highest expansion rates over the next years. Therefore, the expansion of the existing systems or development of new ones for developing countries is a major challenge to be addressed.

G5 - The need to adapt the assessment systems for urban regeneration projects. The NSA systems are mostly designed to evaluate and guide the development of new urban areas, however, authors such as Zheng [52] and Boyle [7] highlight the need to adapt and use these systems to the context of previously build urban environments and their role in achieving global sustainability. Further, on this topic, Cappai [53] explores the reuse of brownfields to meet urban densification and sustainable development requirements. Appendino [54] stresses the need to develop a set of indicators to assess the role that heritage could play in urban sustainable development.

G6 - Regulatory bodies involvement and participation. The results from the literature review show that a key factor for the successful adoption of green communities is government involvement and social participation. To this point, Boyle [7] argues sustainable urban regeneration must be grounded in principles of urban governance, participatory action and an understanding of market dynamics. Therefore, it is necessary for a new iteration of the NSA systems centered on institutional mechanisms to engage citizens and support local action. In fact, Morris [55] conducted a survey on Green Star-CM and concluded that the main factor frequently appointed in the interviews for implementing this system
was the requirement for government involvement and funding. Göçmen [56] and Oliver [57] discusses how planning at the local government level play a fundamental role to play in advancing local and regional sustainability. Encinas [58] argues that the improvement of the obligatory minimum standards may push forward the current voluntary standards by establishing a more demanding baseline that incentivizes competitiveness in the market.

Gap 7 - Need for widening the scale of assessment. While the first sustainability assessment systems and studies focused on the evaluation of single buildings, a growing number of studies are shifting towards larger scales by widening the evaluation to the neighborhoods and cities. To this point, Verovsek [59] stresses that at the neighborhood scale buildings become modules of a system that also considers spaces in-between buildings, public spaces, and infrastructures, the holistic and the community aspect. Addressing sustainability at larger scales opens new opportunities for improved efficiency and better management of local resources, but also opens new challenges because of the increased complexity and interconnectivity. Skaar [60], Aghamolaei [61] and Koutra [62] discuss the importance and difficulties of passing from Zero Emission Buildings to Zero Emission Neighborhoods. Wu [42] discusses how the traditional focus on the green building can transit to green communities by comparing LEED versions for buildings and neighborhoods. Additionally, Pedro [63] addresses the opportunities and challenges of scaling up LEED-ND from the neighborhood towards the city scale. Koutra [62] reviews existing systems and how they address the challenges of sustainability at the building, neighborhood and city level.

G 8 - integration of the NSA with computer-based models. NSA systems are typically expert-based rather than computer-based models, although a few recent studies suggest the integration of both. In this sense, Kuster [64] proposes a near real-time environmental assessment approach for the district level, that combines the expert consultation with ICTs and artificial intelligence to ensure an improved temporal and local adaptability of actual neighborhood sustainability assessments. Oregi [65] further discusses the use of ICT systems in sustainable urban planning projects and the advantages of integrating them in the early stage phase, providing a way of visualizing the sustainability performance scores and means to communicate with stakeholders about the sustainable performance, right from the start of the project. Cheshmehzangi [66] suggests integrating environmental performance analysis for urban design with Computational Fluid Dynamics (CFD) to achieve urban sustainability. Pedro [63] argues that combining sustainability assessment with a computer-based model such as geographic information system (GIS) enables assessing large datasets in reduced processing time. Chen [67] proposes incorporating sustainability assessment into architectural design software such as REVIT to facilitate the integration of sustainability concepts in the normal workflow of architectural professionals.

4 Conclusion

This paper provides a systematic literature review on five of the most widely used urban sustainability assessment systems (BREEAM Communities, LEED Neighborhoods, CASBEE Urban Development, Green Star Communities, and DGNB Urban Districts). Therefore, we analyzed 124 publications on the topic published between 2015-2018 and identified the following eight shortcomings: 1) lack of consensus on sustainability definition and concepts; 2) overlapping and incoherent distribution of criteria and weighting; 3) need to widen the scope by considering, for instance, more socio-economic factors; 4) little flexibility to local adaptation; 5) need to adapt assessment systems for urban regeneration projects; 6) call for regulatory bodies participation and involvement; 7) need to widen the assessment scale; 8) quest for integration with computer-based models. Despite providing a systematic review of recent literature, this study is limited to journal articles found by the selected databases between 2015-2018, within the urban planning field. Therefore, future work can consider expanding the time range and a more detailed analysis of each of these gaps considering hypothesis for improvement. Overall, these findings can be a starting point for researchers and practitioners to formulate new assessment systems or adapt the existing ones, thereby promoting the continued development of this field.
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