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Multiscalarity in International Sustainable Assessment Systems: A Qualitative Comparison of LEED, CASBEE, BREEAM, DGNB and ESTIDAMA on Building, Neighbourhood and City Scale

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Abstract. Sustainable assessment systems have been developed for evaluating different scales of the built environment (building, neighbourhood and city). Multiple scale assessments are necessary as only their coexistence can allow recognition of the environmental, social and economic sustainability of the whole built environment. The integration of assessments of different scales can provide efficient methods and better synergies in the urban fabric. This paper analyses the different scales of the most widespread systems (LEED, BREEAM, CASBEE, DGNB, Estidama) and attempts to define how the indicator systems on different scales relate to each other by comparison on four levels (general, category, index and indicator). The results show that the different scales of an assessment scheme mainly work as individual certification systems, but there are strong connections between building and neighbourhood systems. The comparison indicates that the city scale assessments have the most different characteristics, mainly because building and neighbourhood scale contains prescriptive measures that require action, while the city scale has descriptive indicators that monitor the status of the city. Based on the conclusions, options for further studies includes comparison of building systems for operation phase and city systems; a further analysis of indicator scale connectivity for determining the quality and quantity of system integrations between the three scales.

1. Introduction

Indicators are the main tools for the measurement of urban sustainability [1]. Sustainable assessment systems have been developed for evaluating different scales of the built environment, such as building, neighbourhood and city assessments. Multiple scale assessments are necessary as only their coexistence can allow recognition of the environmental, social and economic sustainability of the whole built environment. However, only a few organizations developed and promoted together assessments for the different scales in the same scheme. From these, building and neighbourhood scale assessments are well tested and in use, but city scale assessments are just now developing. Therefore, it is time to analyse the question: How the indicator systems on different scales relate to each other?

The integration of assessments of different scales can provide more efficient methods and better used synergies available in the urban fabric. Therefore, this paper analyses the different scales of 5 sustainability assessment systems, selected based on their number of assessed scales, popularity, public availability and coverage of different locations: LEED, BREEAM, CASBEE, DGNB and ESTIDAMA.



Table 1. Sustainable assessment systems analysed in the paper

	Building scale	District scale	City scale
BREEAM	BREEAM International New Construction 2014	BREEAM Communities 2012	
CASBEE	CASBEE for buildings (New construction) 2014	CASBEE for urban Development 2014	CASBEE – City (Pilot version) 2015
LEED	LEED Building Design and Construction	LEED Neighborhood Development	LEED Cities
Estidama	Estidama Pearl Building	Estidama Pearl Community	
DGNB	DGNB New construction	DGNB Districts	

2. Literature

Literature on analysis and comparison of building, neighbourhood and city sustainability assessment systems are collected in the following along with literature on the comparisons of the different scales.

2.1. Literature on building scale assessment systems

Building scale comparisons are usually made between 4–6 sustainability assessment systems, always including LEED and BREEAM. Mattoni et al. 2017 [2] defined six indicator categories (site, water, energy, comfort and safety, materials and outdoor quality) and concluded that among the reviewed systems the Energy aspect was the most represented. Illankoon et al. 2017 [3] aimed to establish key categories and identified them as Site, Energy, Water, IEQ, Material, Waste and pollution, and Management. Li et al. 2017 [4] provided review of the existing literature on comparative research of green building assessments and concludes that a four-level assessment method (general, category, criterion, indicator level) would provide comprehensive analysis and highlights the need for more indicator level assessment. Haapio and Viitaniemi 2008 [5] compared environmental assessment tools by only focusing on their general characteristics, with the conclusion that their comparison is almost impossible as their main principles (like building types, the users, their life cycle phases assessed) are different. Similarly, Nguyen and Altan 2011 [6] compared general characteristics of 5 assessment systems, but with a wider variety of topics (popularity and influence, availability, methodology, applicability, data collecting process, accuracy and verification, user-friendliness, development and results presentation) and gave a ranking of the systems. The ranking showed that LEED and BREEAM are the strongest assessment tools mainly due to their robust methodology, wide applicability and user friendliness. Awadh 2017 [7] compared the building scale systems of LEED, BREEAM, GSAS and Estidama focusing on how they cover the 4 pillars of sustainability and concluding that all of them are focused on the environmental pillar while the social pillar got the least importance.

2.2. Literature on neighbourhood scale assessment systems

On the neighbourhood scale Fawzi et al. 2016 [8] reviewed widely used sustainability assessment tools for urban design and development to compare their aim, structure, assessment methodology, scoring, weighting and suitability for application in different locations. It also aimed to determine the coverage of the pillars of sustainability of different assessment systems and concluded that economic and cultural aspects have marginal coverage. Reith and Orova 2015 [9] also focused on the inclusion of the pillars of sustainability in neighbourhood assessment systems and concluded that DGNB has a good coverage of all aspects of sustainability, while CASBEE mainly focuses on the environmental aspects.

Sharifi and Murayama 2014 [10] compared LEED, BREEAM and CASBEE through their application on real case studies, also stating the dominance of the environmental aspects of sustainability. Haapio 2012 [11] also analysed the same 3 assessment systems, but more focusing on the comparison of their used categories and ratings, region of the origin, site location and the covered issues. Tam et al. 2018 [12]

defined 9 neighbourhood sustainability aspects (building, economy, location, community, energy, resources, ecology, infrastructure, transportation) and assessed their coverage in 20 sustainability assessment systems.

2.3. Literature on city scale assessment systems

City scale sustainability assessment are developed, but these are usually either location specific or developed to benefit a certain technology provider. Wide range of literature exists on the analysis of city scale indicator systems, for example: Mori and Christodoulo 2012 [13], Feleki et al. 2018 [14] who compare internationally recognized assessment systems. Also, ISO 37120-2018 ‘Sustainable development of communities’ [15] defines a standardised version of urban sustainability indicators. However, city scale versions of the widespread international sustainability assessment systems are not compared due to their relatively small number and novelty.

2.4. Literature on multiscale analysis of assessment systems

There a few indicators related analysis that assesses different urban scales ([16], [17]), but only a fraction of them provide comparison between building-urban-city levels of indicators systems. Doan et al. 2017 [18] compares the building and neighborhood scale systems of BREEAM, LEED, CASBEE and Green Star NZ focusing on how they cover the 4 pillars of sustainability. They conclude that building assessments cover mainly environmental topics and society and procedural topics for a lesser extent. In comparison with building scale systems, neighborhood tools have evolved considerably to assess Social and Economic issues as well, whole environmental and social indicators are still the main focus. Klemes (2015) [19] compares multicriteria assessment systems such as LEED, BREEAM, SBTtool, CASBEE and Green Globes on building scale, BREEAM, CASBEE and LEED on neighborhood scale and European Common Indicators, Estidama, CASBEE-City, Global City Indicators, Urban Sustainability Index and Indicators for Sustainable Development Goals on city scale. However, the different scales were not compared.

3. Methodology

The main questions of this paper are answered by the comparison the assessment systems on a general and category, index and also on indicator level as suggested by Li et al. (2017) [4]. The main topics of the different scales and the goals and calculation method of their correlating indicators provides information on how integrated the 3 scales within an assessment system type are.

As literature exists for the comparison of assessment systems that are on the same scale, this research focuses on finding the common patterns on each scale and then comparing them to the others as well.

The general comparison consists of the following steps:

- Determination of viewpoints: for the general comparison the following viewpoints were included: general characteristics (year of publication, system developer, system operator), category level information (main categories, number of indicators, existence of mandatory indicators, scoring method, data collection method, pricing) target area (target country, target users), applicability (assessed project phases, assessed project type, assessed functions) and connecting services (connecting assessment tool, price of the tool, quality of results display in tool, connected incentives, connecting consultancy services).
- Data collection about the assessment systems in a summary table
- Comparison of results on the same scale and determinations of similarities and differences
- Comparison on different scales, highlighting the topics where a system differs from the two others

The category comparison consists of similar steps, as the list of categories are collected from the assessment systems, then they are compared on each level and then the connections between the three scales are determined.

The goal of the index comparison is to group the different credits from the indicator systems into a uniform credit category system so that their coverage can be analysed (due to different weighting method in each system currently only the number of credits in each category are counted). For this, a common credit categorisation was determined for each scale based on the following literature:

- Building scale: the literature review-based categorisation of Illankoon et al. 2017 [3] mentioned in Chapter 2.1. was chosen for the building scale analysis
- Neighbourhood scale: The index categorisation of Reith and Orova 2015 [9] were chosen based on the similar methodology of their research
- City scale: On city scale the categorisation of ISO 37120-2018 is used

The indicator comparison consists of the following steps:

- To showcase the differences, and connections between indicators within each scale two issues were selected for analysis: energy use reduction and air quality
- For the two issues the relevant indicators are collected from all systems and compared
- The viewpoints of the comparison are: indicator requirements, calculation methods, benchmarks

4. Results of comparison

4.1. Result of general comparison

The general comparison showed that the systems on the different scales has a lot of common characteristics, but there are also items where each system family have different approach (e.g.: scoring method is different for LEED, BREEAM, CASBEE, DGNB and Estidama; the building and neighbourhood function that can be assessed is different in each system; the Estidama and CASBEE systems has mandatory usage for a specific type of buildings in their developer country; location dependency: LEED awards extra points for regionally important credits, CASBEE and Estidama has specific indicators relevant for their developer countries). However, there are some instances where one scale is distinctly different from the other two:

- Users: the main target group for requiring and applying building and neighbourhood scale indicators are real estate developers who target to increase the value of their property. However, for city scale indicator systems the local government is the main target client.
- Phase of assessment: the investigated building and neighbourhood scale assessment systems evaluate the projects design and construction phase, while the city scale systems assess the operations of the city
- Connecting data collection and tracking tool: for building and neighbourhood scale indicator systems the data collection methods for the relevant project information are individual and helped with little or no assistance (except for CASBEE). On the city scale both systems have standardised data collection method. In case of LEED the Arc platform is used, CASBEE has an excel based assessment tool.

4.2. Result of category comparison

The comparison of the categories of the indicator systems shows that three (CASBEE, DGNB, Estidama) of the five assessment systems have the same categorisation for the two or three different scales they assess. In the case of LEED and BREEAM the categories are different on each scale. The LEED categories on building and city scale have three topics that are similar (energy, water, waste) while the neighbourhood scale show zero similarities with city scale, and only one with the building scale (Regional priorities). In case of the BREEAM systems, the categories for energy, materials, transport and land use and ecology are the same, with an addition of 5 other categories on building and 2 on neighbourhood scale.

4.3. The results of index comparison

Table 2. Result of index comparison on building scale

	LEED	CASBEE	BREEAM	DGNB	Estidama
Site	11	5	12	7	19
Energy	9	5	9	3	11
Water	8	2	6	1	8
Indoor Environment Quality	11	13	7	9	19
Material	4	9	6	5	10
Waste and pollution	8	8	12	1	9
Management	1	0	5	8	4
Other	2	6	1	3	6

The building scale index comparison shows that every category is represented in each system except for the Management category in CASBEE. Also, there are some indexes that are not fitting to any of the categories. These indexes are related to innovation, cost, maintenance and adaptability. Table 2 also show that the Site and Indoor Environment Quality categories are covered with the most indexes, meanwhile the Management category is covered with the lowest number of indexes.

Table 3. Result of index comparison on neighbourhood scale

	LEED	CASBEE	BREEAM	DGNB	Estidama
Healthy environment	2	0	4	4	3
Pollution and risks	3	1	3	1	1
Water efficiency and waste man.	5	1	5	6	14
Material	1	1	2	1	5
Energy efficiency	2	3	1	6	6
Ecology	6	2	5	6	4
Sustainable sites	24	6	22	16	19
Management, quality of service	2	2	3	6	3
Economic aspects	3	1	4	11	2
Community	8	3	9	13	6

The results of the neighbourhood scale comparison (Table 3) shows that every index category is covered by at least one indicator from each system except for CASBEE. A few categories are represented with only one indexes, such as the Material category in LEED and BREEAM, the Economy, Pollution, Water and Material categories in CASBEE and the Pollution and risks category in DGNB and Estidama. In summary, the Material category is the least and the Sustainable sites category is the most covered by the indexes.

Table 4 shows that the high number of index categories from ISO 37120 are not covered fully by either system. There are no indicators for the Fire and emergency response, Governance, Telecommunication and innovation and Wastewater categories. Only the Health and the Education categories have more than one index for both systems.

Table 4. Result of index comparison on city scale

	LEED	CASBEE		LEED	CASBEE
Economy	1	2	Safety	1	3
Education	2	2	Shelter	2	1
Energy	1	5	Solid waste	2	1
Environment	0	2	Telecomm. and Innovation	0	0
Finance	1	1	Transportation	1	0
Fire and emergency response	0	0	Urban planning	0	1
Governance	0	0	Wastewater	0	0
Health	2	5	Water and sanitation	1	0
Recreation	0	1			

When comparing the index analysis on the different scales the different categories can be connected. The connections are shown in Table 5, with the categories without coverage from the indexes in *Italic*. The table shows that the category that is most unique to the building scale is Materials, as there is no such category on city scale and on neighbourhood scale it is the least covered category. The Neighbourhood scale has two additional categories to the ones on building scale: Economy and Community. Economy related issues are present on the building scale for a few systems counted in the Other category, but Community is a new category. On city scale neither the Material nor the Management category are present. The covered category unique for this scale is Education.

Table 5. Index category connections between the three scales

Building	Neighbourhood	City
Site	Ecology, Sustainable sites	Environment, Recreation, Transportation, Urban planning
Energy	Energy efficiency	Energy
Water	Water efficiency and waste management	Water and Sanitation, Wastewater
Indoor Env. Quality	Healthy environment	Health
Material	Material	-
Waste and pollution	Pollution and risks	Solid waste, <i>Fire and emergency response</i>
Management	Management, Quality of service	-
-	Economy	Economy, Finance
-	Community	Safety, shelter
-	-	Education
-	-	<i>Governance, Telecomm. and Innovation</i>

4.4. Results of comparison on indicators scale

The index scale comparison showed that Site, Energy, Water, Waste and Air Quality aspects are covered by all scales. Two aspects were selected for indicator scale comparison, one measuring operational processes (Energy, Water, Waste) and one measuring a momentary state of the development (Air quality or Site): Energy and Air quality. The comparison of indicators related to the sustainability goal of Energy use reduction shows:

- Building scale – either primary energy use reduction is the main measure, or the aspect is included in an LCA (DGNB). The calculation method for the indicators is either dynamic simulation (LEED, Estidama) or steady state calculation (BREEAM)
- Neighbourhood scale – generally equals with the sum of building energy uses with the addition of infrastructure energy usage.

- City scale – the main measure is GHG emissions and not energy usage. For CASBEE sector specific energy use is calculated.

The analysis on Air quality indicators showed different approaches on the three scales:

- On building scale several indicators are present in the systems targeting air quality improvements (Table 6). One of the most important indicators is the increase of ventilation rate, which is present in all systems. However, only LEED and Estidama has the same calculation method (calculation according to ASHRAE 62.1) but their benchmarks are different (LEED has higher ventilation rate increase benchmark for achieving points). Meanwhile CASBEE uses system specific rates, DGNB refers to EN 15251 and BREEAM to national standards.
- On neighbourhood scale the indoor air quality is not considered, neither outdoor air quality.
- On city scale LEED uses Median Air Quality Index which measures pollutant concentration (CO, NO₂, O₃, SO₂, PM_{2,5}, PM₁₀), similarly to CASBEE that considers Ox (photochemical oxidant concentration)

The indicator comparison shows that generally the building and neighbourhood scale indicators have similar methods, but the city scale uses different measures to describe an environmental aspect.

Table 6. Requirements for air quality in the assessment systems

	LEED	CASBEE	BREEAM	DGNB	Estidama
Increase ventilation rate	x	x	x	x	x
Ban smoking on site	x	x	x	x	x
Minimize VOC emissions	x	x	x	x	x
Position of outdoor air intakes	-	x	x	-	-
Implement CO ₂ monitoring	x	x	x	-	x
Implement IAQ testing	x	-	x	x	-
Implement construction IAQ measures	x	-	x	x	x
Increase filtration efficiency	x	-	x	-	-
Avoid asbestos in building materials	-	-	x	-	-
Install entryway systems	x	-	-	-	-
Prevention of cross-contamination	x	-	x	-	-

5. Conclusions, discussion

The comparison of the different scales of urban environment shows that while building and neighbourhood assessments have strong connections both in their general methods, categories, indexes and indicators, the newer city scale tools have the most different characteristics. One of the main differences is that the Building and neighbourhood scale contains prescriptive measures that require action, while the city scale has descriptive indicators that monitor the status of the city. The category and index comparisons showed that on building scale the environmental dimension of sustainability has the highest importance, but neighbourhood and city scales include more social aspects.

On indicator scale the two examples showed that the connection between building and neighbourhood scale is high. The city scale also shows potential for higher level connections, especially data can be shared between the three scales. Generally, the building and neighbourhood scale have closer connections both in the type of indicators, the calculation methods and issues considered. As data sources on city scale are often scarce, a better integration of the calculation methods of the three scales could increase the uptake and success of city scale assessments. For this, new requirements could be developed for building and neighbourhood scale to ease city scale integration.

In summary, the different scales of an assessment scheme mainly work as individual certification systems, their better integration to achieve better energy, water and materials use efficiency, higher liveability, and environmentally conscious sustainable development, should be further developed.

6. Outlook and Further studies

Options for further studies includes comparison of building systems for operation phase and city systems (as they would both assess the same phases). It is also worth to consider a further analysis of indicator scale connectivity, with assessing all indicators. Based on this assessment a development of measures for determining the quality and quantity of system integrations between the three scales can be achieved.

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