Sustainability Assessment of Buildings Indicators

Subjects: Engineering, Civil

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The building sector is responsible for a high environmental impact, namely during construction, maintenance, demolition, and lifetime. It is then urgent to develop tools for guiding all stockholders to make buildings more sustainable. In order to make the sustainability assessment of a building, it is necessary to make a survey of the most appropriate parameters for this analysis and organize them hierarchically.

green buildings rating systems sustainability assessment systems

1. Sustainability Certification Tools for Buildings

Parallel to academic research, government-owned/non-profit organizations onset the development of building certification tools. The first building certification tool was developed in the UK in 1990, and it was called BREEAM (Building Research Establishment's Environmental Assessment Method) [1]. Some years later, France published a new tool, the HQE (High environmental quality), while in 1998, the USA launched the LEED tool (Leadership in Energy and Environmental Design). With the arrival of the new millennium, more certification systems were developed. In Portugal, the LiderA system was disclosed in 2000 and more recently, in 2017, the SBToolPT Urban, a branch of the SBTool, was reported by U. Minho [2][3].

The two best-known rating tools are BREEAM and LEED. BREEAM can be applied to several types of buildings, such as new constructions, infrastructures, in-use or refurbishment, while LEED has different guidelines for building design + construction, residential, operations + maintenance, among others. The present manuscript addresses the International New Construction Documentation by BREEAM and the Building Design and Construction guide by LEED [2][3]. BREEAM International New Construction 2016 has 10 different categories–9 environmental and 1 innovation category–and assessment issues, as shown in **Table 1**.

Table 1. BREEAM International New Construction 2016 categories and assessment issues (Adapted from [4]).

Management	Health and Wellbeing
Project brief and design	Visual comfort
Life cycle cost and service life planning	Indoor air quality
Responsible construction practices	Safe containment in laboratories

Commissioning and handover	Thermal comfort
Aftercare	Acoustic performance
	Accessibility
	Hazards
	Private space
	Water quality
Energy	**Transport**
Reduction of energy use and carbon emissions	Public transport accessibility
Energy monitoring	Proximity to amenities
External lighting	Alternative modes of transport
Low carbon design	Maximum car parking capacity
Energy-efficient cold storage	Travel plan
Energy-efficient transport systems	
Energy-efficient laboratory systems	
Energy-efficient equipment	
Drying space	
Water	**Materials**
Water consumption	Life cycle impacts
Water monitoring	Hard landscaping and boundary protection
Water leak detection	Responsible sourcing of materials
Water efficient equipment	Insulation
	Designing for durability and resilience
	Material efficiency
Waste	**Land use and ecology**
Construction waste management	Site selection
Recycled aggregates	Ecological value of site and protection of ecological features

Operational waste	Minimizing impact on existing site ecology
Speculative floor and ceiling finishes	Enhancing site ecology
Adaptation to climate change	Long-term impact on biodiversity
Functional adaptability	
Pollution	**Innovation**
Impact of refrigerants	Innovation
NO_x emissions	
Surface water run-off	
Reduction of nighttime light pollution	
Reduction of noise pollution	

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Each category has several credits. During the building assessment, the total number of credits achieved is determined. For each category, the fraction of credits obtained (ratio between the number of credits obtained and the maximum number of credits for this category) is multiplied by the category weighting, giving out the category score (in %). Adding the 10 category scores, the final BREEM score is obtained. The final score is then categorized into one of the final six BREEAM ratings, as shown in **Table 2**.

Table 2. BREEAM rating benchmarks.

BREEAM Rating	% Score
Outstanding	≥85
Excellent	≥70
Very Good	≥55
Good	≥45
Pass	≥30
Unclassified	<30

In order to achieve a given BREEAM rating, the minimum overall score must be met, as well as the minimum standards established for said rating. The LEED certification tool–v4.1 Building Design and Construction–has some similarities to the BREEAM rating tool. Instead of minimum standards, the LEED certification tool has prerequisites and credits for the different categories. The distribution is shown in **Table 3**, where prerequisites start with an asterisk (*).

Table 3. LEED v4.1 Building Design + Construction Scorecard (prerequisites start with an asterisk *) (Adapted from [5]).

Indoor Environmental Quality	Location and Transportation	Sustainable Sites
* Minimum indoor air quality performance	LEED for neighborhood development location	* Construction activity pollution prevention
* Environmental tobacco smoke control	Sensitive land protection	* Environmental site assessment
* Minimum acoustic performance	High-priority site and equitable development	Site assessment
Enhanced indoor air quality strategies	Surrounding density and diverse uses	Protect or restore habitat
Low-emitting materials	Access to quality transit	Open space
Construction indoor air quality management plan	Bicycle facilities	Rainwater management
Indoor air quality assessment	Reduced parking footprint	Great island reduction
Thermal comfort	Electric vehicles	Light pollution reduction
Interior lighting		Site master plan
Daylight		Tenant design and construction guidelines
Quality views		Places of respite
Acoustic performance		Direct exterior access
		Joint use of facilities
Water Efficiency	**Energy and Atmosphere**	**Materials and Resources**
* Outdoor water use reduction	* Fundamental commissioning and verification	* Storage and collection of recyclables construction and demolition
* Indoor water use reduction	* Minimum energy performance	* Waste management planning
* Building-level water metering	* Building-level energy metering	* PBT source reduction-Mercury
Outdoor water use reduction	* Fundamental refrigerant management	Building lifecycle impact reduction
Indoor water use reduction	Enhanced commissioning	Building product disclosure and optimization-EDP
Optimize process water use	Optimize energy performance	Building product disclosure and

		optimization-Sourcing of raw materials
Water metering	Advanced energy metering	Building product disclosure and optimization-Material ingredients
	Grid harmonization	PBT source reduction-Mercury
	Renewable energy	PBT source reduction-Lead, cadmium, and copper
	Enhanced refrigerant management	Furniture and medical furnishings
		Design for flexibility
		Construction and demolition waste management
Integrative Process	**Innovation**	**Regional Priority**
* Integrative project planning and design	Innovation	Regional priority
Integrative Process	LEED accredited professional	

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- ▪ The building must use reasonable LEED boundaries.
- ▪ The building must comply with project size requirements.

A minimum of 40 points are required to obtain a positive certification. The four levels of certifications are displayed in **Table 5**.

Table 4. LEED certification levels.

LEED Certification	Total Points
Platinum	80+
Gold	60–79
Silver	50–59
Certified	40–49

The developed sustainability assessment tools assigned different names to similar categories. While BREEAM and LEED sustainability assessment tools share common names such as “Energy”, “Water”, and “Materials”, there are some categories that are only found in some of these two tools (for example, LEED has the “Sustainable Sites” category, while BREEAM has the “Management”). Zulkefli et al. [6] compared the indicators of different rating tools and organized them into the primary themes of sustainability (Environment, Social and Economic Indicators). A total of 87 indicators were proposed to assess the sustainability of buildings.

In 2015, the European Commission started the development of a common European approach to assessing the environmental performance of buildings. The proposed tool, which is still under development, is known as Level(s), which is a framework that has core indicators of sustainability for buildings [5]. The tool has been developed with six macro-objectives in mind, as depicted in **Table 5**.

Table 5. Level(s) macro-objectives and their definition (Adapted from [7]).

Level(s) Macro-Objectives	Definition
1- Greenhouse gas and air pollutant emissions along a building life cycle	Minimize the total greenhouse gas emissions along a building's life cycle, from the cradle to the grave, with a focus on emissions from building operational energy use and embodied energy.
2- Resource-efficient and circular material life cycles	Optimize the building design, engineering and form in order to support lean and circular flows, extend the long-term material utility and reduce significant environmental impacts.
3- Efficient use of water resources	Make efficient use of water resources, particularly in areas of identified long-term or projected water stress.
4- Healthy and comfortable spaces	Create buildings that are comfortable, attractive and productive to live and work in and which protect human health.
5- Adaptation and resilience to climate change	Futureproof building performance against projected future changes in the climate in order to protect occupier health and comfort and to minimize long-term risks to property values and investments.
6- Optimized lifecycle cost and value	Optimize the life cycle cost and value of buildings to reflect the potential for long- term performance improvement, inclusive of acquisition, operation, maintenance, refurbishment, disposal and end of life.

Out of the 16 core indicators presented in **Table 6**, 3 of them are composite indicators (Life cycle Global Warming Potential, Construction and demolition waste and materials and Indoor air quality), five of them are qualitative (Lighting and visual comfort, Acoustics and protection against noise, Increased risk of extreme weather events, Increased risk of flood events and Value creation and risk exposure) and one (Bill of quantities, materials and lifespans) is reported as information reporting.

Table 6. Level(s) macro-objectives and their corresponding indicators (Adapted from [7]).

Greenhouse gas and air pollutant emissions along a building's life cycle	Use stage energy performance
	Lifecycle Global Warming Potential

Resource-efficient and circular material life cycles	Bill of quantities, materials and lifespans
	Construction & demolition waste and materials
	Design for adaptability and renovation
	Design for deconstruction, reuse and recycling
Efficient use of water resources	Use stage water consumption
Healthy and comfortable spaces	Indoor air quality
	Time outside of thermal comfort range
	Lighting and visual comfort
	Acoustics and protection against noise
Adaptation and resilience to climate change	Protection of occupier health and thermal comfort
	Increased risk of extreme weather events
	Increased risk of flood events
Optimized life cycle cost and value	Life cycle costs
	Value creation and risk exposure

The Level (s) framework is divided into three levels. The first level regards the conceptual design for the building project. It is the simplest level, in which early-stage qualitative assessments are applied to the conceptual design or concepts of the building. The second level covers the detailed design and construction performance of the building. This intermediate level entails quantitative assessments of the designed performance and monitoring of the building. The third and final level encompasses the as-built and in-use performance of the building after completion. It is the most advanced level, and it entails the monitoring and surveying of activity on the construction site and the building, as well as its occupants. The higher the level, the more accurate and reliable the report will be, but the framework is built so that one can choose which level/combination of levels to work at [8].

Finally, Level(s) has four briefings on the key concepts of the framework, as follows:

- ▪ Whole life cycle and circular thinking;
- ▪ Closing the gap between design and actual building performance;
- ▪ Achieving a sustainable renovation;
- ▪ Sustainability has a positive influence on the market value of a property.

2. Compilation of Sustainability Indicators

Sustainability indicators proposed by the present work were compiled into a single list. They were divided into five levels of weighting, where a higher weight was assigned to the indicators shared by an increased number of reviewed rating systems of sustainability. The indicators with higher weights are shown in **Table 7**, and the others with the lowest weights are shown in **Table 8**.

Table 7. Compiled sustainability indicators of the reviewed ratings systems. Higher weighting is related to a higher number of sustainability rating systems that use them.

Weight	Environment	Social	Economic
5	Renewable energy	Design considerations toward safety	Innovation management/new product development
	Thermal comfort	Acoustic and noise control	
	Site selection		
4	Recycled/reused materials	Public transportation access & transportation plan	Use of regional resources
	Indoor air quality performance	Thermal comfort	
		Daylight	
3	Climate Change	Visual quality	Cost of construction
	Noise Pollution	Employment (social aspects)	
	Energy Efficiency	Infrastructure improvement	
	Indoor air quality	Community relationships and involvement	Cost of operation and maintenance
		Public acceptance of the project	
	Visual comfort	Stakeholder engagement/management	
		Sustainable development supported by local laws	
2	Climate change adaptation/disaster risk management	Public Comfort	Regional workers and personnel
		Cultural heritage	Supply and demand sides
	Recycled water	Natural heritage	Marketing price
	Destruction of the stratospheric ozone layer	Workers and personnel comfort	Return on Investment

Weight	Environment	Social	Economic
			Durability of building
	Efficient lighting		Direct job opportunities

Environment	Social	Economic
Workers' and personnel's health and safety	Migration effects	Effects on national economy
Loss of habitats, agricultural farms and trees	Social responsibility	Use of national resources
Construction water quality impact	Social action funding/Concepts of social justice	Enhancement in the capacity of infrastructure
Considering the life cycle of products and services to reduce environmental impacts	Corporate sustainability and organizational culture	Effects on trade balance (national/regional)
Project biodiversity	Labor practices	Financing (loan interests)
Environmental impact assessment project report	Needs assessment of society/people	Opportunity-cost
Environmental tobacco smoke (ETS) control	Human rights	Cost of equipment and their installation
Carbon dioxide monitoring and control	Employee commitment/commitment in the workplace	Distributed income innovation and technological advance
Minimum IAQ performance	Project independence of political factors	
Envelope Insulation	Social impact reports	Stakeholder involvement/participation
Use of environmentally friendly refrigerants and cleaning materials, effective and low-carbon cleaning equipment and machinery	Transparent and competitive procurement processes	Target marketing and benefits
Renewable raw materials	Absence of bureaucracy in the workplace	Effective project control
Hazardous degradable wastes	Contractor–supplier relationship	Best practice strategy
Hazardous non-degradable wastes	Commitment to the stakeholders' needs	Customer-relationship management/Access to a range of customers
Environmental management	Well-defined project scope and	

systems/policy implications	project limitations	
Flood risk assessment strategy to prevent flooding	Holistic view of benefits	Scope control through managing changes
Air Pollution	Product–service systems	Business ethics
Violation of animal's territory	Emphasis on high-quality workmanship	Facility management Technologies/general improvements
Durable materials	Encourage competition	
Non-renewable energy	Implementing a quality management system	Supply chain collaboration
Reuse of processed water	First mover advantage	Effective strategic planning
Non-hazardous recyclable wastes	Culture of accountability	Organizational culture
Non-hazardous non-recyclable wastes	Comprehensive contract documentation	Project outputs emphasis
Environmental management plan for impacts by the Project Management Team (PMT)	Diversification	Ability to pay and affordability
Sustainable project delivery through project stakeholder management	Competitive tendering/comprehensive pre-tender investigation of the project	Environmental/economics accounting
Environmental education and training	Adaptability in project environment	
Eco-efficiency	Intangible asset management	Developing an efficient risk management plan by the PMT
Consistent and predictable load	Multidisciplinary/competent Project Management Team (PMT)	
Up-to-date environmental construction technologies and methods	The role of trust within the PMT	Implementing an effective change management strategy
Environmental responsibility/justice	Following project management phases/processes	
Identify and address choke points	Project manager's leadership style	
Appropriate and flexible environmental design details and specifications	Employing operational decision-making techniques by the PMT	Efficient data processing for decision-making practices
Mold Prevention	Project monitoring and evaluation by the PMT, though previous	Bureaucratic streamlining

	experiences in projects	
Sustainable maintenance	Managing knowledge and awareness to promote sustainable project delivery (PMT)	Internationalization
Acidification potential	Management considerations toward safety	Cargo delivery route & proximity
Establish environmental policy and end-user guide, and manual	Affordability	
	Neighborhood accessibility and amenities	Expenditure on R&D
Low-carbon design	Maximum car parking capacity	Lifecycle costs
Grid harmonization	Places of respite	Reserve funds

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