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Article

Comparative Analysis of Material Criteria in Neighborhood Sustainability Assessment Tools and Urban Design Guidelines: Cases of the UK, the US, Japan, and Korea

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Abstract: Sustainability assessment tools have been developed for building-scale sustainability since the 1990s. Several systems, such as BREEAM (Building Research Establishment Environmental Assessment Methodology), LEED (Leadership in Energy and Environmental Design) and CASBEE (Comprehensive Assessment System for Built Environment Efficiency), are widely used and have been upgraded and adapted to large-scale development. BREEAM Communities, LEED Neighborhood Development and CASBEE for Urban Development have been implemented in the UK, the USA and Japan, respectively. As the notion of sustainable urban design has gained more significance, city governments have set their own guidelines for sustainable standards in urban design based on studies of sustainability assessment tools. This study focused on a comparative analysis of the material criteria embedded for sustainable urban design in BREEAM Communities, LEED-ND (Neighborhood Development) and CASBEE-UD (Urban Development), and the urban design guidelines recently issued in multiple cities, including London, New York, Tokyo, and Seoul. The top master plans and the supplementary guidelines were analyzed to investigate the detailed material criteria. The study examined the differences in the material assessment criteria, evaluation parameters, and descriptions of the neighborhood sustainability assessment tools and the urban design guidelines. The material criteria was

investigated and discussed to summarize the current features and weaknesses as balanced material assessments for sustainable urban development.

Keywords: material; neighborhood sustainability assessment tools; sustainable urban development; BREEAM communities; LEED-ND; CASBEE-UD; urban design guideline

1. Introduction

Many countries are making efforts to develop sustainable cities, and administrative governments and policy councils are becoming involved in setting up tools and guidelines to accelerate the formation of sustainable urban neighborhoods. Among the systems dedicated to assessing, guiding and regulating sustainable approaches in architecture and urban planning, sustainability assessment tools are considered to be reliable in achieving the aim of sustainability [1–3] and have gained interest from authorities [4,5]. Building sustainability assessment tools have been established since the 1990s in many leading countries. They have been continually updated and applied to a multiple range of projects in different types and scales. The most widely applied examples include BREEAM (Building Research Establishment Environmental Assessment Methodology) in the UK, LEED (Leadership in Energy and Environmental Design) in the USA, and CASBEE (Comprehensive Assessment System for Built Environment Efficiency) in Japan. Efforts have been made to further enlarge the assessment scale to include communities and cities [6]. These tools have been divided into many specialties, including neighborhood development and city planning: BREEAM Communities, LEED-ND (Neighborhood Development) and CASBEE-UD (Urban Development) [7].

In recent years, neighborhood sustainability assessment tools have become an active research field, especially with the introduction of BREEAM Communities, LEED-ND and CASBEE-UD [8]. Several studies [1,4–10] have compared the categories and evaluation criteria in the neighborhood sustainability assessment tools. These studies provided a general description of the neighborhood sustainability assessment tools [10].

Sharifi and Murayama [7] proposed categories for the assessment tool, including resources and environment, transportation, social, economic, location and site selection, pattern and design, and innovation. Luedertiz *et al.* [11] set out 11 categories related to the principles of sustainability, including function, structure, context, leakage effects, socio-ecological system integrity, livelihood sufficiency and opportunity, intra-generational equity, inter-generational equity, resource maintenance and efficiency, socio-ecological civility and democratic governance, and precaution and adaption.

Komeily *et al.* [1] analyzed neighborhood sustainability assessment tools to examine their ability to define and measure the sustainability goals, to identify the most frequent criteria and to offer a balanced approach to handling the timely and imminent issues.

Ameen *et al.* [8] drew attention to the aim, structure, assessment methodology, scoring, weighting and suitability for the application in different geographical contexts of the various assessment tools. The study highlighted the differences that exist in the relative importance and share of mandatory *vs.* optional indicators in both the environmental and social dimensions. Through a review of all criteria, the researchers devised a list of the main indicators and the sub-indicators for the six assessment tools,

depending on the three fundamental dimensions of sustainability (economy, environment, society and culture).

Reith *et al.* [10] presented the methodology and results of a comparative investigation of five assessment tools. By means of a three-level comparison and the indicator evaluation, the different neighborhood sustainability assessment systems were compared both in general and in detail. To make the indicators comparable, a common categorization system was developed by analyzing 25 different classifications from sustainability assessments, sustainable city indexes, *etc*.

As the pursuit of sustainability in neighborhood design provoked neighborhood sustainability assessment tools, major transitions in the thinking and practice of urban design guidelines were required. Neighborhood sustainability assessment tools are intended to indicate the level of sustainability that is achievable in the design process, implementation and operation of a neighborhood development project. They are not mandatory programs for all developments; rather, they are voluntary, preferential tools applied by the project initiators. To promote sustainable design and planning strategies in the decision-making process, many city authorities have integrated items and criteria of the sustainability assessment tools into their urban design guidelines [5,12–17]. In some countries and municipalities, whole systems have even become obligatory for new developments [10,18]. With such shifts in approaching the urban development, hundreds of sustainable urban projects have been initiated across the world [19].

All of the assessment tools and urban design guidelines classify the evaluation items differently. Nevertheless, site selection, access to transportation, energy efficiency, water savings, atmosphere quality, and resource selection are major elements targeted by sustainable design [3,4,6].

Among those, materials and resources have attracted attention in approaching a range of issues on material life-cycle impacts, natural resource depletion, pollution, health, and physical materialization tools for other environment-friendly strategies for energy, water and the atmosphere [11]. In particular, for urban designers, landscape designers and architects, materials are the main subject when dealing with environmental problems in their design disciplines, as cities cannot contribute to overall sustainability unless the built environments are sustainable [1,20]. The material matter a neighborhood is built from [21], including infrastructures, landscapes and buildings, serves as the medium with which urban designers, landscape designers and architects work. Its intrinsic qualities and limitations not only determine the approach to design and form, but also remain subservient to issues of sustainability [21]. The material matter has the ability to define the neighborhood environment and the urban conditions.

In a review of literature, a disparity in analyzing, categorizing and measuring materials in neighborhood sustainability assessment tools is discovered, in addition to academic perspectives. The study by Komeily *et al.* [1] focused more on the environmental aspect, raising concern over the adoption of a physical/material-based approach to sustainability. Material was seen as independent or separable from healthy social lives and relationships as well as from the local economy, production and economic power.

Braulio-Gonzalo *et al.* [22] comprehensively reviewed the indicators of 13 tools, which were developed to assess urban sustainability, and proposed a new, locally adapted structure of indicators. In their proposed structure, extensive subcategories and materials objectives were included in one of the 14 categories, but materials were considered intrinsic aspects of the building. The research pointed out that "materials", one of those least emphasized in the indicators, brought together only a few indicators. Ameen *et al.* [8] considered materials in common indicators such as "Material management"

and "Sustainable building", and materials only fell into the environmental dimension of sustainable urban design.

Reith *et al.* [10] proposed a categorization method with buildings, economies and locations. The subcategory list showed materials, resources, recycling, resource management and waste under the economy category, and existing buildings, façade, interior, roof, *etc*. under the building category. The indicators evaluated by their capability to integrate and measure the environmental, economic and social dimensions of sustainability included "materials" and "recycling" as environment-related goals. The result from this study doesn't deliver the integrated dimensions in approaching materials.

In neighborhood sustainability assessment tools, in conjunction with urban design guidelines, many researchers do not intensively focus on the material aspects [11,23]. From this view, this paper conducts an in-depth analysis of the material criteria in neighborhood sustainability assessment tools and the descriptive standards on materials in urban design guidelines.

In analyzing and classifying items as they relate to material, the availability of detailed descriptions concerning material is the main reference point. For comparative analysis, this paper proposes a framework considering an integrative way to approach sustainability in materials. The framework is structured with indicators that identify widely accepted crucial issues in sustainability [1], which are referred to as the Circle of Sustainability (or the Three Pillars of Sustainability [24]).

"Indicators" have been extensively discussed in literature examining the sustainability assessment tools. Moussiopoulos *et al.* [25] argued that sustainability indicators were developed to provide environmental, social and economic information. Haapio [4] defined indicators as quantitative, qualitative or descriptive measures that, when periodically evaluated and monitored, show the direction of change, corresponding to the criteria. Indicators can be seen as a significant tool to translate collected data into manageable units of information [25]. Braulio-Gonzalo *et al.* [22] presented indicators involving all aspects of sustainability on the neighborhood and city scale. The study classified one indicator from LEED-ND, three indicators from BREEAM Communities, and seven indicators from CASBEE-UD in the category "materials". The subcategories of "materials" listed low-impact materials, certified reference materials, reused and recycled materials, and local materials.

The more extensive subcategories of sustainable materials classified from selected references can be used as "indicators" to measure the deficiency of criteria related to the materials in neighborhood development. In addition, the framework with indicators can be introduced as an approach to review and compare material sustainability in neighborhood sustainability assessment tools and urban design guidelines.

The rest of paper is organized as follows. Section 2 introduces the framework of sustainable material assessment, the circle of sustainable materials, and the use of indicators as a comparison methodology. Section 3 identifies and compares the material criteria in neighborhood sustainability assessment tools, including BREEAM Communities, LEED-ND and CASBEE-UD. Section 4 outlines the urban design guidelines' material requirements in London, New York, Tokyo, and Seoul. Section 5 verifies the relationship between neighborhood sustainability assessment tools and urban design guidelines and looks at the differences in material-related items, depending on the regional features. Section 6 highlights the results of this study and speculates for further study.

2. Framework of a Sustainable Material Assessment: Circle of Sustainable Materials

2.1. Comparison Methodology: Indicator-Based Framework

The study presents a detailed comparative analysis of material related items among three neighborhood sustainability assessment tools and four urban design guidelines to understand the relationship between assessment tools and design guidelines. In addition, the similarities and differences of the tools and guidelines are investigated to evaluate their material sustainability. A framework with indicators measuring different sustainable dimensions is used as the comparison methodology.

The framework must be built on a generic assessment criteria that not only covers the core sustainability requirements, but also forces thinking across the boundaries of the three pillar categories of environment, social and economic [23]. However, this paper does not aim to provide a comprehensive review of the recent assessment literature, but rather seeks to provide a platform for further evaluation and comparison of the material criteria included in the neighborhood sustainability assessment tools and the urban design guidelines. While other researchers have focused on developing their own interpretations and definitions [26], this paper uses the framework as a measure to analyze how materials in neighborhood sustainability assessment tools and urban design guidelines are approached and prescribed with a balance among the different dimensions.

Indicators are proposed by reviewing particular cases, which is the most popular approach to measure urban sustainability [19]. An observed datum or variable becomes an indicator only once its role in the evaluation of a phenomenon has been established [27]. An indicator is a simple measure of a sustainability parameter, a tool to quantify a system requirement. The indicator comparison is the most detailed method of comparison, where the core components of the sustainability assessment tools and urban design guidelines are collected and evaluated [10].

Braulio-Gonzalo *et al.* [22] presented a list intended to increase knowledge sharing among different practices. It was also used to select a common indicators list of sustainable urban development that is used to develop new urban development plans and improve the decision-making process in the sustainability assessment of urban design.

Likewise, the indicator-based framework of a sustainable material assessment can organize, measure and diagnose the existing details of material requirements, both of neighborhood sustainability assessment tools and of urban guidelines, to lead to critical review and improved development of urban guidelines.

2.2. Base of Framework: Circle of Sustainability

For a holistic and inter-disciplinary approach, sustainability addresses the integration of environmental, social and economic aspects [28], as shown in The Circle of Sustainability (Figure 1) [7,29]. This is widely used in cities and urban settlements by a series of global organizations, and it helps to improve the understanding of sustainable urban design, which balances the social and economic effects of the built environment, while mitigating the environmental impacts [8]. In the interpretation of sustainability, environmental concerns often gain more attention than social or economic factors. For comprehensive sustainability assessment purposes, there is a need for a means to ensure adequate attention to all important factors [23].

In addition, the Circle of Sustainability has some important advantages, including for the sustainability assessment application [23]. There exist studies and literature [23,26,30] that review the sustainability assessment framework, based on the Circle of Sustainability, to interrelate the economic, social and environmental dimensions of sustainability. Researchers have emphasized the need for a comprehensive and integrated framework for sustainability assessment.

Many studies on indicator-based comparison of neighborhood sustainability assessment tools [8,10] show material as an environment indicator. However, in this study, the three pillars in the Circle of Sustainability are proposed to be applied to sustainable material assessments.

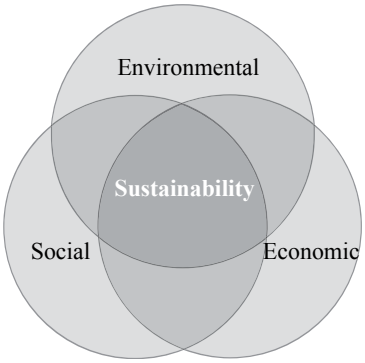


Figure 1. Circle of sustainability: three legs of sustainability.

2.3. Sustainable Material Indicators

Indicators measure different subjects in their approach to sustainability. The indicators are evaluated by their ability to integrate and measure the environmental, economic and social dimensions of sustainability [10]. To investigate the similarities and differences in the measures of sustainability assessment tools and urban guidelines in comparing material matters, the indicators had to be collected from other sources, such as from a material assessment database and system or from material sustainability assessment standards and literature. The Pharos, Building Materials and Furnishings Sustainability Assessment Standards by the Whole Building Design Guide (WBDG) [31], the University of Michigan Sustainability Assessment Framework [32], and the Ten Shades of Green [33] were referenced to provide indicators for the framework. The final framework listed with indicators was developed by means of categorizing, organizing, eliminating and redefining indicators, as shown in Tables 1–4.

The Pharos [34,35] provides a tool to evaluate building materials based on the environmental performances of the products. The Pharos framework also adopts the three pillars concept with a partial adjustment. The framework is organized into three categories: (1) Environment Resources; (2) Social Community; (3) Health Pollution. The Pharos lens visualizes the environmental, social and health-related performance of products. The ratings sub-categories for Environmental and Resources include renewable materials, embodied energy, renewable energy, embodied water, solid waste, and habitat restoration. The Social and Community category is subcategorized into manufacturer's occupational and consumer safety, fairness and equity, community contributions, and corporate leadership. Health and Pollution includes Indoor Air Quality (IAQ)/user exposure, toxic materials, impact on global warming, air quality and water quality.

Table 1. Sustainable material indicator list—the pharos.

Category	Sub-Category	Material-Related	Environmental	Economic	Social	Redefined Indicator
Environmental Resources	Renewable materials	×	×			Resources
	Embodied energy	×	×	×		Efficiency
	Renewable energy					
	Embodied water					
	Solid waste	×	×			Resources
	Habitat restoration	×	×			Habitat and Settlement
Social Community	Manufacturer's occupational and consumer safety	×	×		×	Health and Safety
	Fairness and equity					
	Community contributions	×			×	Locality
	Corporate leadership					
Health Pollution	IAQ/user exposure	×	×		×	Health and Safety
	Toxic materials	×	×		×	Health and Safety
	Impact on global warming	×	×			Habitat and Settlement
	Air quality and water quality	×	×			Health and Safety

Table 2. Sustainable material indicator list—whole building design guide.

Reference	Category		Material-Related	Environmental	Economic	Social	Redefined Indicator
Building Materials and Furnishing Sustainability Assessment Standards	Product content		×	×			Resources
	Health and environment		×	×		×	Health and Safety
	Energy		×	×	×		Efficiency
	Recycling and reclamation		×	×		×	Resources
							Preservation
	Water conservation		×	×			Habitat and Settlement
	Air quality		×	×			Health and Safety
	Social responsibility		×			×	Harmony
	Innovation		×				
Whole Building Performance	Environmental	Ecosystems and biodiversity	×	×			Habitat and Settlement
		Natural resources	×	×			Resources
	Economic	Direct cost	×		×		Life-Cycle Cost
		Indirect cost	×		×		Efficiency
	Social	Health, safety and welfare	×	×		×	Health and Safety
		Cultural capital	×			×	Harmony
		Quality of life impact					

Table 3. Sustainable material indicator list—University of Michigan Sustainability Assessment.

Category	Sub-Category	Material-Related	Environmental	Economic	Social	Redefined Indicator
Environmental	Energy					
	Materials consumed	×	×		×	Resources Health and Safety
	Water use					
	Food consumption					
	Land and vegetation	×	×			Habitat and Settlement
	Air emission	×	×			Health and Safety
	Effluents					
	Solid waste	×	×			Resources
	Hazardous waste	×	×			Health and Safety
Social	Management quality					
	Wages and benefits					
	Health and safety	×	×		×	Health and Safety
	Training					
	Freedom of association					
	Non-discrimination					
	Community development					
	Sustainability in education					
Economic	Investment					
	Revenues and expenses					

Table 4. Sustainable material indicator list—ten shades of green.

Category	Material-Related	Environmental	Economic	Social	Redefined Indicator
Low energy/high performance					
Replenishable sources	×	×			Resources
Recycling	×	×		×	Resources Preservation
Embodied energy	×	×	×		Efficiency
Long life, loose fit	×		×	×	Durability and Adaptability Preservation
Total life-cycle cost	×		×		Life-Cycle Cost
Embedded in place	×			×	Locality
Access and urban context					
Health and happiness	×	×		×	Health and Safety
Community and connection					

The WBDG's Building Materials and Furnishings Sustainability Assessment Standards include the following criteria: integrate environmental and life-cycle thinking into the product design process; manufacture products to quantify the environmental impacts from their manufacturing and to reduce or remove those impacts; maximize product longevity through long-term value; manage product's end of life, including collection, processing, recycling and composting; be involved in the local community through corporate governance; and demonstrate financial health and innovation. The standard data

elements are product content, health and environment, energy, recycling and reclamation, water conservation, air quality, social responsibility and innovation. The standards are used in government programs, such as Executive Order 13514 Federal Leadership in Environmental, Energy, and Economic Performance (5 October 2009) addressing greenhouse gas emissions and other environmental attributes of products. In addition, the WBDG Federal Green Construction Guide for Specifier [36] includes performance-based requirements that are consistent with the Guiding Principles for Federal Leadership in High Performance and Sustainable Building and with ASTM2432, Standard Guide for General Principles of Sustainability Relative to Buildings. The Whole Building Performance encompasses environmental, economic, and social impacts.

Similarly, the University of Michigan Sustainability Assessment uses framework utilizing the triple bottom line concept, recognizing environmental, social and economic spheres of sustainability. Each sphere is divided into categories and further divided into indicators. Environmental categories include water use and greenhouse gas emissions, social categories include wages and community development and financial categories include revenues and investment policies.

Ten Shades of Green, an exhibition organized by the Architectural League, showed examples of work that combined environmental responsibility with formal ambition. A context for evaluating all works of architecture and land planning was created to embrace a range of concerns, from technical efficiency to communal well being and emotional resonance. Ten aspects of sustainability were discussed in detail. The list of ten aspects starts with quantifiable technical issues and leads to contextual and urban issues and qualitative socio-cultural issues.

2.4. Framework of a Sustainable Material Assessment: Circle of Sustainable Materials

Based on the Circle of Sustainability and an analysis of references, this paper proposes "The Circle of Sustainable Materials" to integrate the most comprehensive concepts in a sustainability assessment, as presented in Figure 2, according to the following principles:

- Each sphere includes three equal indicators in the environmental, economic, and social issues categories.
- Indicators are proposed to encompass the common values of sustainable materials.
- Environmental indicators are Resources, Health and Safety and Habitat and Settlement.
- Economic indicators are Life-Cycle Cost, Durability and Adaptability and Efficiency.
- Social indicators are Locality, Harmony and Preservation.
- Each Indicator can be assessed for the different uses of materials as they are applied in urban designs. The material application sphere is categorized into (1) infrastructure; (2) landscape and (3) building.

Environmental indicators relate to protection of the natural environment and the impact on ecology. Economic indicators refer to the wise, efficient and responsible use of resources for long-term benefits. Social indicators support creating a sound and livable community [1]. The basic set of indicators is shown with definitions in Table 5.

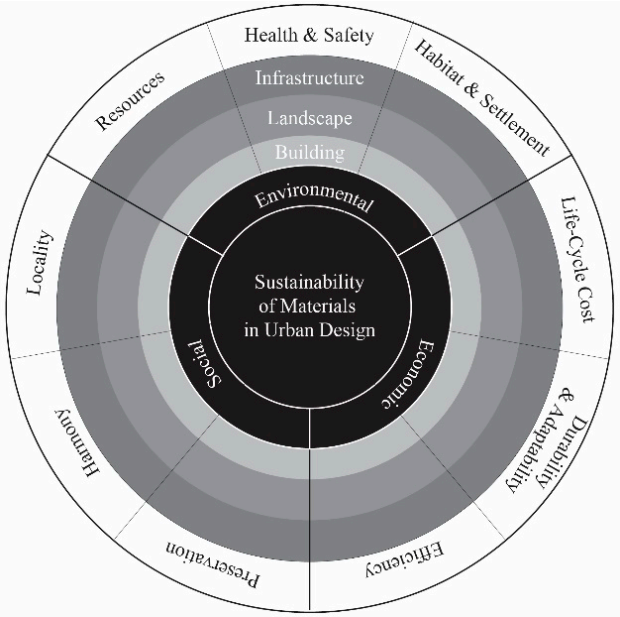


Figure 2. Circle of sustainable materials: based on the three legs of sustainability.

Table 5. Indicator definitions.

Category	Indicator	Definition
Environmental	Resources	Select materials from non-depletable or near inexhaustible sources and promote recycling to reduce the impact on resources
	Health and Safety	Use non-toxic materials with low emissions and eliminate waste and pollution
	Habitat and Settlement	Use materials with low impact on nature and ecology
Economic	Life-Cycle Cost	Use materials with a low environmental impact during their life-cycle, including manufacturing, implementation and demolition
	Durability and Adaptability	Use materials with a long life and flexible character to easily accommodate change
	Efficiency	Use materials with low embodied energy and low overall material demands
Social	Locality	Encourage the use of locally produced or manufactured materials
	Harmony	Encourage the use of materials suitable to the regional context to help reintegrate and minimize negative impacts upon their settings
	Preservation	Reuse and conserve existing buildings and infrastructures

3. Material Criteria in Neighborhood Sustainability Assessment Tools: BREEAM Communities, LEED-ND and CASBEE-UD

This section examines the differences in material assessment criteria, evaluation parameters and methods, and descriptions of neighborhood sustainability assessment tools: BREEAM Communities (Version 2012), LEED-ND: Plan v4 (Version 2014) and CASBEE-UD (Version 2014).

3.1. BREEAM Communities (Version 2012)

BREEAM Communities is released by the Building Research Establishment (BRE) in the UK (2009, Rev. 2012). The assessment criteria are grouped into five categories, which are then considered in the following three steps: Step 1, establishing the principles; Step 2, determining the layout; and

Step 3, designing the details [37]. The material items are included in Resources and Energy, and Transport and Movement.

The BREEAM Communities includes low-impact materials, sustainable buildings and resource efficiency to drive healthy, safe and habitable communities and environments. Its unique item is the specification of durable shelter seating materials in public transport facilities.

3.2. LEED-ND: Plan v4 (Version 2014)

LEED-ND is a system for evaluating neighborhood design that was developed in partnership with the Congress for the New Urbanism, the Natural Resources Defense Council and The U.S. Green Building Council (USGBC) (2009, Rev. 2014). Many of its criteria, particularly site location and neighborhood pattern, reflect the New Urbanist principles and are inspired by traditional neighborhood design. These criteria address five broad point categories. Among those, material items are included only in Green Infrastructure and Buildings [38].

The LEED-ND credits include recycled content and solid waste management of infrastructure. In addition, the "heat island reduction" credit specifies non-roofing and roofing materials with an SRI (Solar Reflectance Index) to reduce heat islands. The Regional Priority criteria can be used to evaluate the locality of materials in an urban development, even though the current details do not include the use of local or regional materials.

Additionally, LEED-ND has a "Certified Green Building" pre-requisite and credit. It requires a building in the project to be certified under the LEED rating system, or through a green building rating system that requires review by an independent, impartial, third-party certifying body accredited by an IAF-accredited body to ISO/IEC Guide 65 or, when available, ISO/IEC 17065 [38]. Multiple material related credits in the sustainability assessment tools are categorized under material and resource.

In case of LEED-NC v4, its major changes were highlighted in material credits when it was upgraded in 2014. There were minor changes in old credits related to materials including: building reuse; materials reuse; recycled content; regional materials; rapidly renewable materials; and certified wood, and new credits were introduced, such as building life-cycle impact reduction (LCA), and building product disclosure and optimization [39,40].

However, LEED-NC v4 has limitations; certification doesn't mean that a building has met the criteria for any material and resource credits. For example, 13 possible points are assigned under the category of materials and resources [41] in the LEED-NC v4, 2014 Edition, and only 40 points out of a total of 110 points are required for certification. Therefore, a building with only a few points in material and resource can be certified in LEED-NC. The pre-requisite of "Certified Green Building" is not necessarily relevant to the material requirement in the assessment tool. This means that LEED-ND is unable to capture the interactions between buildings and their neighborhood developments. It has weaknesses to consider when integrating the multiple scales of material criteria within the neighborhood sustainability assessment tool.

3.3. CASBEE-UD (Version 2014)

CASBEE-UD was developed by the Japan Sustainable Building Consortium (JSBC) (2006, Rev. 2014). Environment, society and economy classifications are major assessment criteria in adopting the

Three Legs of Sustainability in its structure [42]. In CASBEE-UD, material items are covered in all classifications of environment, society and economy. Out of the major criteria, Environment: Resource, Environment: Nature, Environment: Artifact, Social: Amenity, and Economy: Efficiency/Rationality all have minor items regarding materials.

CASBEE-UD covers almost all the criteria of the circle of sustainable materials, except for the Life-Cycle Cost and Locality, which are not fully integrated in any analyzed sustainability assessment tools, even though it is considered to be an important concept in sustainable material standards. CASBEE-UD assesses the landscape materials, such as pavement, street furniture, lighting and signs, for environmental habitat and settlement and social harmony. When prescribing recycling, CASBEE-UD tends to be more specific on the material types when considering local resources.

3.4. Discussion on Assessment Tools

As listed in Tables 6–8, BREEAM Communities and LEED-ND include more classifications of minor items than CASBEE-UD. As a result of the analysis of the detailed description of minor items related to materials, it was found that when evaluating the sustainability of urban design and development, each neighborhood sustainability assessment tool places a different weight on materials depending on its assessment criteria. As shown in Figures 3 and 4, CASBEE-UD has the highest quantity ratio and weight of material assessment items, compared to LEED-ND and BREEAM Communities.

Table 6. List of the material-related criteria in BREEAM (Building Research Establishment Environmental Assessment Methodology) communities.

Division	Categories	No. of Items	Weight (%)	Related to Material		Minor Items Related to Material
				No. of Items	Weight (%)	
Assessment Criteria	Governance	4	9.3	0	0	
	Social and Economic Wellbeing	17	42.7	0	0	
	Resources and Energy	7	21.6	4	4.1	Sustainable Buildings
					2.7	Low-impact Materials
					2.7	Resource Efficiency
					2.7	Existing Buildings and Infrastructure
	Land Use and Ecology	6	12.6	0	0	
	Transport and Movement	6	13.8	1	2.1	Public Transport Facilities
Total	5	40	100	5	14.3	

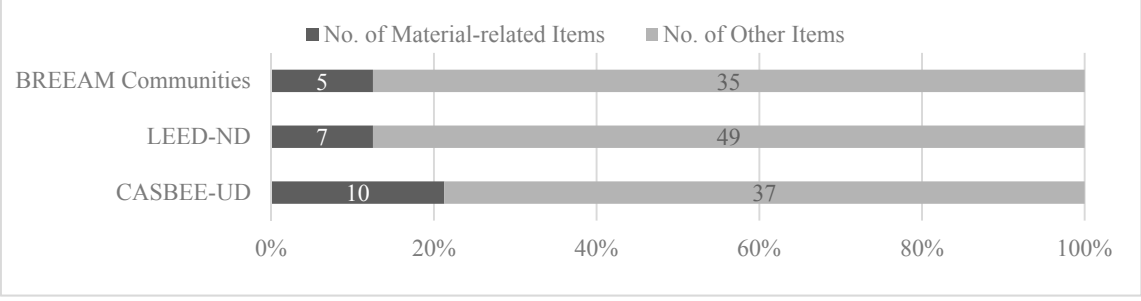


Figure 3. Quantitative comparison of material criteria in neighborhood sustainability assessment tools.

Table 7. List of the material-related criteria in LEED-ND (Leadership in Energy and Environmental Design for Neighborhood Development) (P: Prerequisite, C: Credit).

Division	Categories	No. of Items	No. of Points	Related to Material		Minor Items Related to Material
				No. of Items	No. of Points	
Assessment Criteria	Smart Location and Linkage	14 (P5, C9)	28	0	0	
	Neighborhood Pattern and Design	18 (P3, C15)	41	0	0	
	Green Infrastructure and Buildings	21 (P4, C17)	31	7 (P1, C6)	0	(P) Certified green buildings
					5	Certified green buildings
					1	Building reuse
					2	Historic resource preservation and adaptive reuse
					1	Heat island reduction
					1	Recycled and reused infrastructure
					1	Solid waste management
	Innovation	2 (C2)	6	0	0	
	Regional Priority	1 (C1)	4	0	0	
Total	5	56 (P12, C44)	110	7 (P1, C6)	11 (10.0%)	

Table 8. List of the material-related criteria in CASBEE-UD (Comprehensive Assessment System for Built Environment Efficiency for Urban Development).

Division	Categories	No. of Items	Related to Material			
			No. of Items	Weight (%)	Minor Items	
Assessment Criteria	Environment: Resource	9	3	0.7	Water resource-Sewage	• Rain water permeable surface and equipment
				2.8	Resources–Recycling–construction	• Wood material • Recycled content
	Environment: Nature	8	4	2.8	Greenery–Ground greening	
				2.8	Greenery–Building top greening	• Rooftop greening • Wall greening
				1.4	Biodiversity-Preservation	• Landform
	Environment: Artifact	1	1	11.1	Environmentally friendly buildings	
	Social: Impartiality/Fairness	2	0			
	Social: Safety/Security	6	0			
	Social: Amenity	7	3	2.8	Culture–History and culture	
				2.8	Culture–View	• Consideration for formation of townscape and landscape in the district • Harmonization with the periphery
	Economy: Traffic/Urban structure	6	0			

Table 8. *Cont.*

Division	Categories	No. of Items	Related to Material		
			No. of Items	Weight (%)	Minor Items
Assessment Criteria	Economy: Growth Potential	4	0		
	Economy: Efficiency/Rationality	4	1	2.8	Energy system–Updatability and expandability
Total	3 (9)	47	10	29.9	

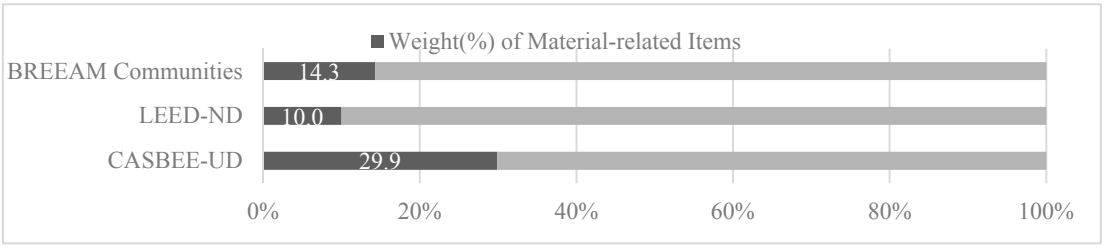
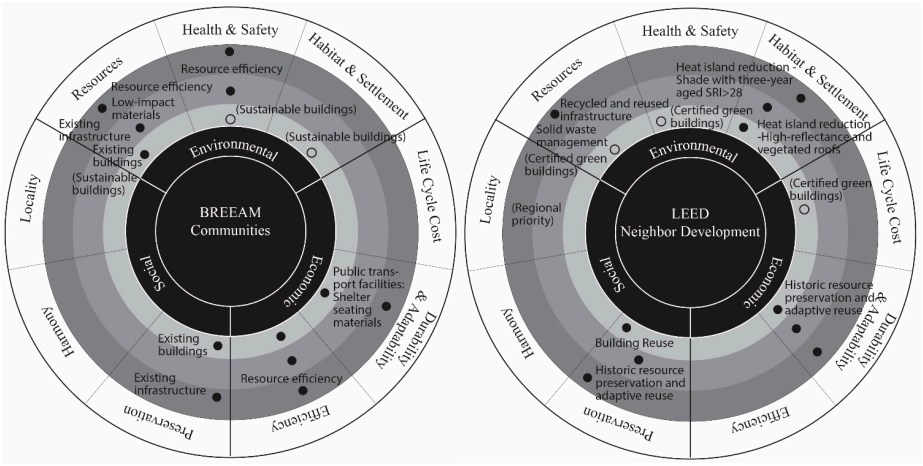


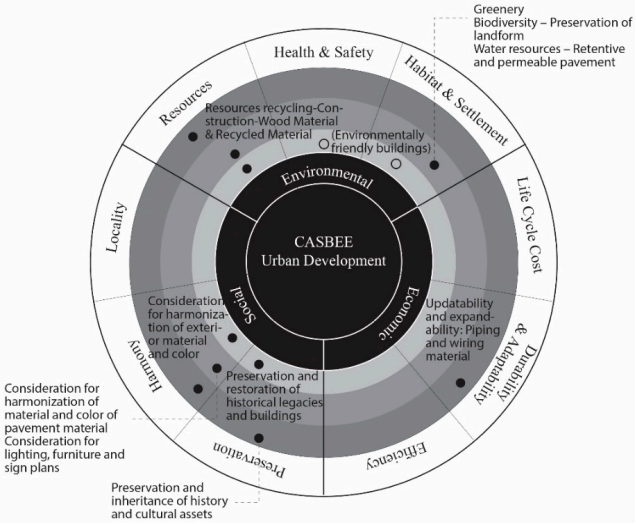
Figure 4. Weight comparison of material criteria in neighborhood sustainability assessment tools.

For comparative analysis of detailed items, the previously proposed circle of sustainable materials was adopted as a tool in Table 9. In Figure 5, all the assessment tools cover the three spheres of sustainability, but BREEAM Communities and LEED-ND tend to focus more on the reuse of existing infrastructure and buildings, approaching resource issues environmentally and achieving social values in preservation. CASBEE-UD approach materials as resources to be saved and recycled, but also as factors contributing to environmental sustainability and harmonized urban structures. Although BREEAM Communities and LEED-ND were developed as global sustainability assessment tools, national priorities may affect the approach to sustainable materials in urban development. The USA and the UK may emphasize the value of preservation and the reuse of existing structures, including buildings and infrastructure, more, while in Japan, the depletion of resources and the formation of neighborhoods are more urgent issues in urban development.



(a) **(b)**

Figure 5. *Cont.*



(**c**)

Figure 5. Circles of sustainable materials: (**a**) BREEAM Communities; (**b**) LEED-ND; and (**c**) CASBEE-UD.

Table 9. Detailed material criteria in neighborhood sustainability assessment tools. ((text): Partially relevant).

Category	Indicator	Application	BREEAM Communities	LEED-ND	CASBEE-UD
Environmental	Resources	Infrastructure	Existing infrastructure	Recycled and reused infrastructure	Resources recycling-Construction-Wood Material
			Low-impact materials	Solid waste management	Resources recycling-Construction-Recycled Material
			Resource efficiency		
		Landscape	Low-impact materials	N/A	Resources recycling-Construction-Wood Material
			Resource efficiency		Resources recycling-Construction-Recycled Material
		Building	Existing buildings	(Certified green buildings)	Resources recycling-Construction-Wood Material
			Sustainable buildings		
			Low-impact materials		Resources recycling-Construction-Recycled Material
			Resource efficiency		
	Health and Safety	Infrastructure	Resource efficiency	N/A	N/A
		Landscape	Resource efficiency	N/A	N/A
		Building	(Sustainable buildings)	(Certified green buildings)	(Environmentally friendly buildings)
			Resource efficiency		
	Habitat and Settlement	Infrastructure	N/A	Heat island reduction-Shade with three-year aged SRI > 28	N/A
		Landscape	N/A	Heat island reduction -Shade with three-year aged SRI > 28	Greenery Biodiversity–Preservation of landform
					Water resources–Retentive and permeable pavement
		Building	(Sustainable buildings)	Heat island reduction -High-reflectance and vegetated roofs	(Environmentally friendly buildings)

Table 9. *Cont.*

Category	Indicator	Application	BREEAM Communities	LEED-ND	CASBEE-UD
Economic	Life-Cycle Cost	-	N/A	(Certified Green Buildings)	N/A
	Durability and Adaptability	Infrastructure	Public transport facilities: Shelter seating materials	Historic resource preservation and adaptive reuse	N/A
		Landscape	N/A	Historic resource preservation and adaptive reuse	Updatability and expandability: Piping and wiring material
		Building	Public transport facilities: Shelter seating materials	Historic resource preservation and adaptive reuse	N/A
	Efficiency	Infrastructure	Resource efficiency	N/A	N/A
		Landscape	Resource efficiency	N/A	N/A
		Building	Resource efficiency	N/A	N/A
Social	Preservation	Infrastructure	Existing infrastructure	Historic resource preservation and adaptive reuse	Preservation and inheritance of history and cultural assets
		Landscape	N/A	Historic resource preservation and adaptive reuse	N/A
		Building	Existing buildings	Building reuse Historic resource preservation and adaptive reuse	Preservation and restoration of historical legacies and buildings
	Harmony	Infrastructure	N/A	N/A	N/A
		Landscape	N/A	N/A	Consideration for harmonization of material and color of pavement material Consideration for lighting, furniture and sign plans
		Building	N/A	N/A	Consideration for harmonization of exterior material and color
	Locality	-	N/A	(Regional priority)	N/A

4. Material Criteria in Urban Design Guidelines: London, New York, Tokyo and Seoul

This section focuses on an analysis of the material criteria and requirements in urban design guidelines recently issued in London, New York, Tokyo, and Seoul. The criteria and requirements are then compared with the neighborhood sustainability assessment tools. Among the many guidelines and standards by each municipality, this study focused on the top master plan setting up the future vision and directions of city planning as well as on the supplementary guidelines, depending on their availability, according to each municipality's urban guideline structure.

4.1. London

The Greater London Authority (GLA) published the London Plan as a spatial development strategy (SDS), focusing on sustainability and spatial plan (2004, Rev. 2015). As circumstances change, such as economy or population, the London Plan has been maintained, altered or, if necessary, replaced. Under the GLA Act 1999, the London Plan took into account the following three cross-cutting themes: economic, social and environmental. The plan then set out a fully integrated framework of the three legs of sustainability for capital development over the next 20 to 25 years, and forms a part of the

development plan for Greater London. The local plans for the 32 London boroughs need to be in general conformity with the London Plan, and its policies guide decisions on planning applications by councils and the mayor [43].

The latest London Plan (2015) is composed of eight chapters: Context and strategy, Places, People, Economy, Response to climate change, Transport, Living places and spaces, Implementation, monitoring and review. Figure 6 shows the ratio of material-related policies in each category of the London Plan. Among a total of 121 policies, there are 11 material-related policies: six policies in Response to Climate Change and five policies in Living places and spaces.

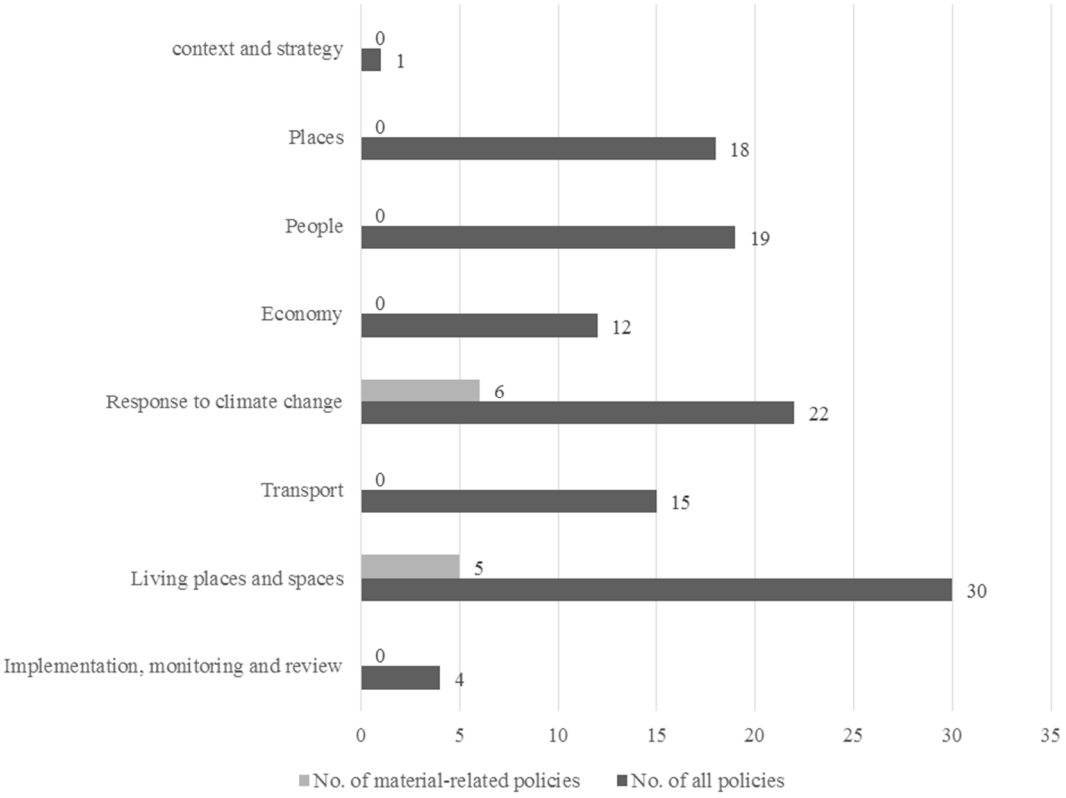


Figure 6. Ratio of material-related policies in the London Plan (2015).

Table 10 lists 11 material-related policies, along with their description. They cover the broad spectrum of sustainable material, such as locality, reuse and recycling, reduction, waste, health, pollution, and high performance. As a result, the London Plan covers all economic, social and environmental issues [44]. Because it is the overall city plan, it doesn't provide sufficient details in its description.

The Supplementary Planning Guidance (SPG) [45] documents were published to provide further details on particular policies in the London Plan. It is used to support statutory development plans, not as an alternative to them. The latest version of Sustainable Design and Construction SPG (2014) provides guidance on the implementation of London Plan policy 5.3: Sustainable Design and Construction, as well as a range of policies. SPG is composed of three chapters: Resource management, Adapting to climate change and greening the city, and Pollution management: land, air, noise, light and water. Although various material-related practices have been introduced in multiple chapters, "2.7 Material and Waste" provides detailed guidance by phase, as shown in Table 11 [46].

Table 10. List of the material-related policies in the London Plan (2015).

Chapter	Topic	Policy	Description
Response to Climate Change	Mitigation	5.3 Sustainable design and construction	• Securing sustainable procurement of materials • using local supplies where feasible
	Adaptation	5.9 Overheating and cooling	• Minimizing overheating and also meeting its cooling needs
	Waste	5.16 Waste net self-sufficiency	• Encouraging reuse and reduction in the use of materials
		5.17 Waste capacity	• Space for the storage of recyclable and compostable materials and waste
	Aggregates	5.20 Aggregates	• Reuse and recycling of construction, demolition and excavation waste (95% by 2020) • Extraction of land-won aggregates within London
	Contaminated land and hazardous substances	5.22 Hazardous substances and installations	• Managing hazardous materials
Living Spaces and Places	Place shaping	7.6 Architecture	• The highest quality materials • The local architectural character
		7.7 Location and design of tall and large buildings	• Incorporating the highest standards materials
	Historic environment and landscape	7.8 Heritage assets and archaeology	• Conserving sympathetic to their materials
	Air and noise pollution	7.14 Improving air quality	• Not releasing toxins
	Protecting open and natural environments	7.19 Biodiversity and access to nature	• Positive gains for nature through materials

Table 11. List of the material-related items in the sustainable design and construction (SPG) (2014).

Chapter		The Mayor's Priorities and Best Practice		
Resource Management	2.3 Site layout and building design	Reuse of existing building		
	2.4 Energy and carbon dioxide emission	Use less energy	Passive design measures	• Optimizing insulation • Minimizing cold bridging • Optimizing thermal mass • Using light colored materials
	2.7. Material and waste	Design stage	Prefabrication	
			Deconstruction	
			The choice of materials	• Managing existing resources • Using the BRE Green Guide to Specification • Ensuring that materials are responsibly sourced • Sourcing materials from local sources • "Healthy" materials • Robust materials
		Construction phase	Demolition material	
			Waste hierarchy	
			Historic material	
		Occupation	Storage for recyclables, organic, material and waste	
Adapting to Climate Change and Greening the City	3.2 Tracking increased temperature and drought	Overheating	Using materials with a high thermal mass	
			Using materials with high albedo surfaces	
	3.4 Flooding	Flood resilience and resistance of buildings in flood risk areas	Avoiding the use of materials particularly vulnerable to water	
Pollution Management–Land, Air, Noise, Light and Water	4.3 Air pollution	Protecting internal air quality	Robust materials Specifying environmentally sensitive (non-toxic) building materials	
	4.4 Noise	Detailed design considerations	The careful choice of materials	

4.2. New York

The City of New York released the PlaNYC to address its long-term challenges, including the forecasted 9.1 million residents by 2030, the changing climate conditions, an evolving economy, and an aging infrastructure (2007, Rev. 2011). This is a comprehensive sustainability plan for a greener, greater New York [47]. In addition, the Progress Report was published to monitor PlaNYC (2007, Rev. 2014) [48]. The latest version of PlaNYC (2011) launched 127 initiatives in 10 categories, as shown in Figure 7: Housing and neighborhoods, Parks and public space, Brownfields, Waterways, Water supply, Transportation, Energy, Air quality, Solid waste, and Climate change. Some of the initiatives are related to materials, but the major issue in the city is waste management, rather than design and construction materials, as shown in Table 12 [49].

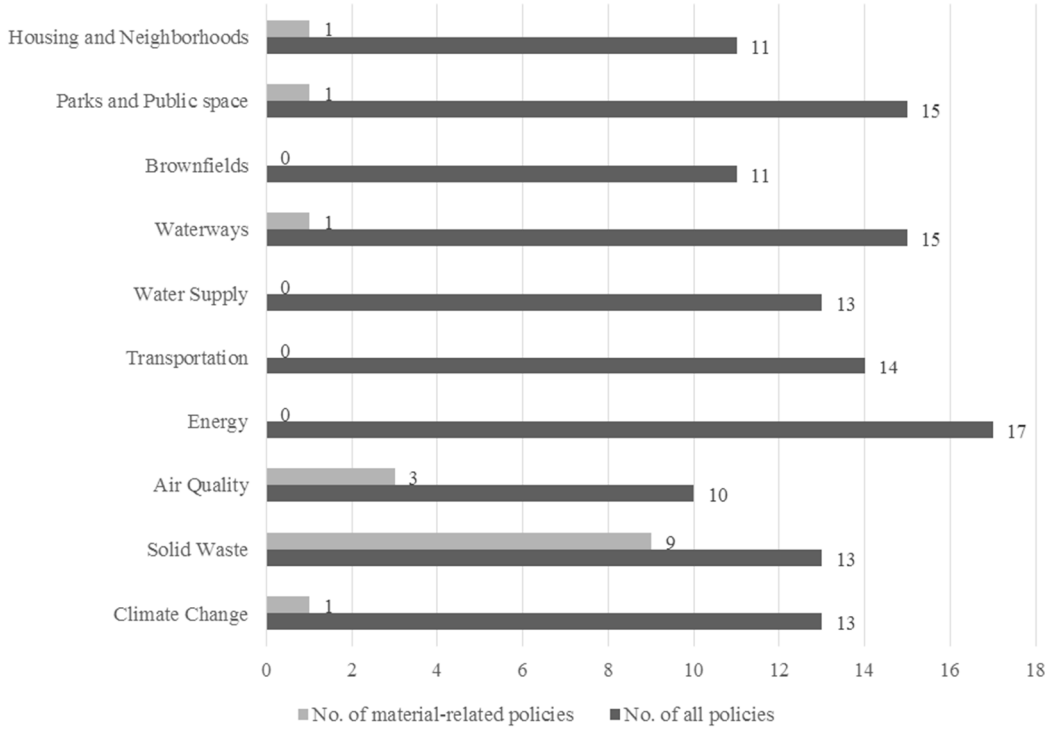


Figure 7. Ratio of material-related policies in the PlaNYC (2011).

All city projects should be informed by PlaNYC. To guide the sustainable development of publicly-owned property, the Department of Design and Construction (DDC) issued several design manuals with more detailed information. The High Performance Infrastructure Guidelines (2005) were published after the High Performance Building Guidelines (1999) to manage the design and construction of streetscape and public right-of-way projects. The Infrastructure Division of DDC worked on the guidelines, in partnership with the non-profit organization Design Trust for Public Space. The guidelines focus on seven dimensions: Site assessment, Streetscape, Pavement, Utilities, Storm water management, Landscape, and Construction practices. The guidelines present the 53 Best Management Practices (BMPs), practical strategies and technical strategies and technical resources for sidewalks, roadways, utility projects, and their adjacent landscaped areas. Among those, six BMPs in three dimensions are related to materials, as shown in Table 13. They provide the materials specifications, with references, and introduce examples in NYC as the precedents [50].

Table 12. List of the material-related items in PlaNYC (2011).

Category	Initiative		Description
Housing and Neighborhoods	Encourage sustainable neighborhoods	8. Increase the sustainability of city-financed and public housing	• Use of non-toxic building materials
Parks and Public Space	Ensure the long-term health of parks and public space	15. Incorporate sustainability through the design and maintenance of all public space	• Develop indicators to measure existing and new sustainability initiatives at DPR related to material resources
Waterways	Use green infrastructure to manage storm water	9. Modify codes to increase the capture of storm water	• Increase recycled materials in all new sidewalk construction.
Air Quality	Update codes and standards	9. Update codes and regulations to improve indoor air quality	• Propose regulations to reduce exposure to toxins released by building materials
Solid Waste	Reduce waste	2. Increase the reuse of materials	• Encourage and increase reuse of materials
	Increase the recovery of resources from the waste stream	3. Incentivize recycling	• Encourage businesses to recycle, and use recyclable and recycled materials through corporate challenges, partnerships, or recognition programs
		4. Improve the convenience and ease of recycling	• Increase recycling
		5. Revise City codes and regulations to reduce construction and demolition waste	• Require use of recycled content in building materials • Require recycling of building materials
		6. Create additional opportunities to recover organic material	• Expand opportunities for communities to compost food waste
		7. Identify additional markets for recycled materials	• Explore expansion of designated plastics
	Improve the efficiency of the waste management system	11. Remove toxic materials from the general waste stream	• Expand Household Hazardous Waste collection program
	Reduce the City government's solid waste footprint	12. Improve the City government's diversion rate	• Develop best practices that address solid waste reduction for procurement and incorporate into Environmentally Preferable Purchasing
Climate Change	Create resilient communities	13. Work with communities to increase their climate resilience	• Improve access to publicly available data on the locations of hazardous material storage in flood zones throughout the city

Table 13. List of the material-related items in the high performance infrastructure guidelines (2005).

Dimension	Best Management Practices (BMPs)	Technical Strategies
Streetscape	SS.5. Increase and Improve Right-of-way Public Space and Green Areas	• Incorporate seating and street furniture into public spaces and throughout streetscape • Use environmentally preferable materials in streetscapes
	SS.7.Optimize Street Lighting and Signaling	• Use environmentally preferable materials and resources
Pavement	PA.3. Maximize Pavement Albedo	• Develop a comprehensive, citywide plan to increase pavement albedo • Consider using light-colored aggregate in asphalt • Consider using high-albedo asphalt coating • Consider conducting chip-sealing on low volume roads • Consider painting sections of pavement with light-colored paint • Consider using Portland cement concrete where possible • Consider using a tinted asphalt or white binder • Consider using alternative soil stabilization resins
	PA.5. Use Reduced-Emission Materials	• Application for asphaltic materials • Application for concrete materials • Application for traffic marking coatings • Application for anti-graffiti coatings • Application for bio-based filter fabric
	PA.6. Use Recycled and Reclaimed Materials	• Develop a recycled and reclaimed materials program • Applications in asphalt concrete • Applications in Portland Cement Concrete (PCC) concrete • Applications in PCC cementitious materials • Applications in pavement sub-base • Non-pavement applications
Construction Practices	CP.4. Implement a Waste Management and Recycling Plan	• Regulate management of C&D waste in contract documents • Employ creative waste management strategies • Coordinate C&D efforts to reduce vehicular miles traveled

The Department of Design and Construction (DDC) of NYC published the Sustainable Urban Site Design Manual (2008), developed by the Structure Division, with a different scope from the High Performance Infrastructure Guidelines (2005). The manual addresses landscape opportunities associated with building projects and offers an introduction to more environmentally, economically and socially responsible urban site design practices for NYC capital projects. The document has four topics: Maximize vegetation, Minimize site disturbance, Water management on urban sites, and Materials in site and landscape design. Each topic focuses on practical recommendations and combines the unique site conditions encountered on many city projects with the appropriate sustainable site design strategies. In addition, it highlights applicable LEED strategies as well as local laws, rules and regulations. In particular, the chapter for Materials in Site and Landscape Design specifies environmentally preferable materials and focuses on strategies to incorporate recycled materials in site features and construction [51], as shown in Table 14.

Table 14. List of the material-related measures in the sustainable urban site design manual (2008).

Chapter	Strategy	Specific Techniques and Descriptions
Water Management on Urban Sites	Storm water management	• Hardscape techniques-porous pavements/ permeable pavers
	Light-colored paving and hardscape	• Light-colored pavement types
	Strategies for incorporating recycled materials	• Planning: survey the existing site • Design: target key items • Construction documents: follow DDC's required specifications • Construction phase: monitor
Materials in Site and Landscape Design	Specific techniques and material descriptions	• Coal fly ash recycled • Blast furnace slag recycled • Plastics recycled • Rubber recycled • Glass recycled • Metals recycled • Organic Waste recycled • Asphalt recycled • Concrete and masonry recycled

4.3. Tokyo

The Bureau of Urban Development established the City Planning Vision for Tokyo (2001, Rev. 2009), which sets the future vision of the city and presents the strategic directions of urban policy. This policy places greater importance on the perspectives of the environment, greenery and cityscape.

The Master Plan for City Planning (2004) is an official plan to define the urban development policy, the disaster prevention policy and the development and maintenance policy of urban residential areas [52]. The Master Plan for City Planning Areas defines the future vision of the city and serves as the foundation to make drafting individual city plans obligatory [53]. The reinforced network between water and greenery and the realization of the city coexisting with the environment are the main themes in the agenda to create a rich urban environment [54].

In parallel to the Master Plan for City Planning, the Bureau of Environment sets up the Tokyo Metropolitan Environmental Master Plan (2008), and Guidelines for Consideration Regarding Urban Planning (2008) [55]. The Tokyo Metropolitan Environmental Master Plan aims to promote a commitment to reduce the effects of climate change, increase and conserve green areas in the city, recycle resources, improve air quality, and a develop a solution to the negative legacy in the environment, including soil contamination. The Plan lists measures under three major sections: creating a high quality and more comfortable urban environment (QC); ensuring a healthy and safe environment (HS); and preserving a subsistent foundation for all living beings (PF), as illustrated in Figure 8.

To preserve subsistent foundation for all living beings, the conservation and recycling of resources is promoted to reduce waste and promote recycling, and to promote sound waste processing and develop a recycling business. In this direction, the targets were as follows: to reduce the amount of final waste treatment; to eliminate the disposal of plastic waste in landfills by promoting plastic recycling; to

increase the use of recycled construction soils; and to create a mechanism that enhances the market value of excellent industrial waste processing companies.

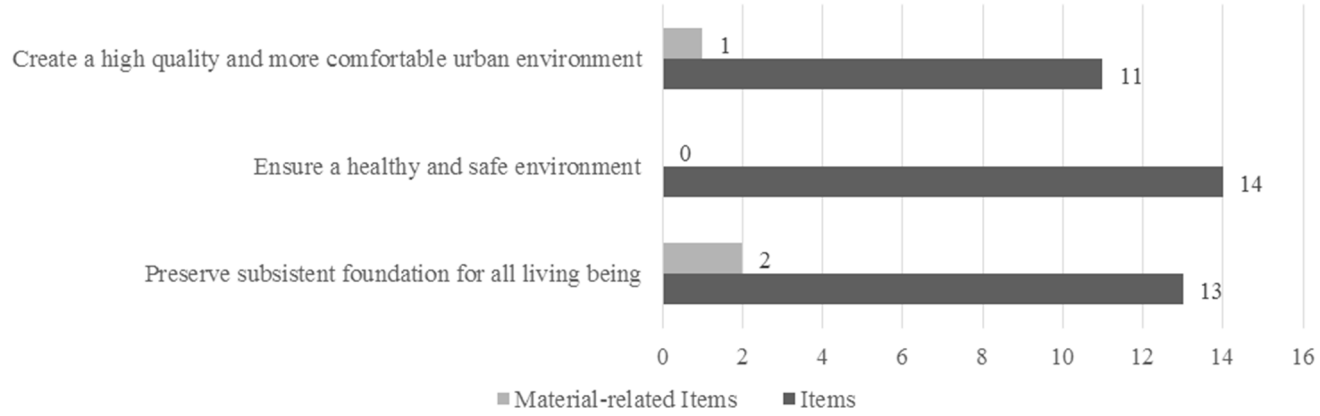


Figure 8. Ratio of material-related items in the Tokyo metropolitan environmental master plan.

In addition, to alleviate heat stress, the following measures were promoted in this master plan: greening, water-retaining pavement, thermal barrier pavement, and highly reflective coatings. In general, the material-related items in the environmental measures of the Tokyo Metropolitan Environmental Master Plan create a high quality and more comfortable urban environment and preserve the subsistent foundation of all living beings. These material-related items are mainly related to the concept of environmental resources and environmental habitats and settlement in the circle of sustainable materials.

The guidelines for consideration regarding urban planning aim to present the urban planning items that private and public companies need to consider in the planning and implementation phases. The guidelines function as a checklist to assess the environmental system. They are organized into three parts: common items for consideration applicable to urban planning, major items for consideration based on the regional characteristics of each zone of Tokyo and major items for consideration based on each characteristic of the various operations involving urban planning [55]. The city is zoned as follows: Center Core Revitalization Zone (CCR), Urban Environment Revitalization Zone (UER), Networking Zone of Suburban Core Cities (SCC), Tokyo Bay Waterfront Vitalization Zone (TBW), and Natural Environment Preservation and Utilization Zone (NPU). The general structure of the guideline maintains three sectors as the Tokyo Metropolitan Environmental Master Plan. The required material approaches are more specific and detailed than CASBEE-UD, while covering most items in CASBEE-UD and differentiating the values of the items according to the regional and operational characters. Tables 15–17 list the material-related consideration items in three parts, categorizing the basic environmentally friendly items and detailing considerations and approaches in urban development.

Table 15. List of the material-related measures in "common items for consideration regarding urban planning".

Sector	Common Consideration Item		Approach
PF	Prevention of generating waste and promotion of recycling of waste	Use of resource recycling Suppression of generating waste and appropriate treatment of waste Promotion of recycling resources and by-products in addition to using reproduced materials	• Consideration of long-life in architectural planning and use of highly durable materials and construction methods • Adoption of highly variable specifications • Use of recyclable materials • Active utilization of reproduced materials • Thorough separation of by-products in construction and reuse of by-products • For temporary installation, selection of reusable materials, and consideration of structure and use
HS	Prevention and reduction of air pollution	Air pollution caused by factories and workplaces–measures for PM, NOx and VOC Prevention of scattering asbestos	• Measures to prevent impacts on the surroundings from air pollutants at construction sites • Inhibiting emission of VOC in outdoor painting and using low VOC paint • Prevention of dust during construction work and conducting research on the optimal scatter-proof measures of asbestos in demolition and renovation
	Reduction of environmental risk caused by chemicals, soil pollution and water pollution	Proper management of chemical materials and risk communication	• Introduction of equipment to reduce emission of chemicals, including VOC to reduce environmental risk
QC	Mitigation of heat island effect	Greening Covering measures Attention to the wind corridor	• Greening of artificial ground, green walls and spaces • Pavement types, pavement materials with high water retentiveness and less thermal storage • Pedestrian pavement types ensuring adequate ventilation
	Landscape, historical and cultural heritage	Attention to landscape Consideration of historical and cultural heritage	• Consideration of building forms, skylines and colors.

Table 16. List of the material-related measures in "consideration on the basis of regional characteristics of zones".

Sector	Zone	Items	
Regional	CCR	• Redevelopment and refurbishment to highlight the regional environmental features • Measures against surface coverings from pavements, buildings and asphalts causing increased heat and energy use • City planning and architecture in consideration of microclimate and thermal environment • Environmental improvement sufficiently utilizing the regional characteristics	
	UER	• Improvement of disaster prevention in dense residential areas with wooden houses	
PF	CCR TBW	• Prevention of generating waste and promotion of recycling waste	
HS	CCR TBW	• Reduction of environmental risk caused by chemicals, soil pollution and water pollution	
	SCC	• Prevention and reduction of air pollution	• Measures to prevent impacts on the surroundings from air pollutants at construction sites
QC	CCR	• Creation of green spaces and waterfront environment • Preservation and restoration of natural environment, biodiversity and ecosystem • Mitigation of heat island effect • Preservation and revitalization of historical and cultural heritage	• On-site greenery, installation of green roofs and green walls • Greening in the dense area with wooden houses • Preserving the region-specific landscape by utilizing historical, cultural buildings and townscapes and residential areas with waterfront and rich green areas
	TBW	• Creation of green spaces and waterfront environment • Preservation and restoration of natural environment, biodiversity and ecosystem	• Use of natural blocks and rockworks for seawalls and waterfront development

Table 17. List of the material-related measures in "consideration on the basis of various operations".

Sector	Operations	Items
PF	Transportation	• Long-term life and use of vehicle facilities and pavements • Use of reproduced or recyclable materials, such as recycled crushed stone • Use of materials with less impact on the environment • Improvement in the recycling ratio of materials and reduction of waste
	Canals, river and other	
	Commercial and business housings and residential	• High thermal insulation / Use of CFC-free insulation material • Separated collection of insulation materials with Freon during building demolition to reduce greenhouse gas • Use of reproduced or recyclable materials such as recycled crushed stone • Use of materials with less impact on the environment • Improvement in the recycling ratio of materials and reduction of waste
	Factory/recreational	
	Site/landfill and port/quarrying	• Reduce the volume of construction by-products through reuse and recycling
	Waste and sewage treatment	• Use of CFC-free insulation material • Separated collection of insulation materials with Freon during building demolition to reduce greenhouse gas • Use of reproduced or recyclable materials such as recycled crushed stone • Use of materials with less impact on the environment • Extended use of buildings with long-term life to save resources and reduce waste
	Energy supply	
HS	Transportation	• Reduction of NOx, SPM emissions • Implementation of low-noise pavement and road greening • Consideration of exterior materials and paint of elevated roads and buildings
	Canals, river and other Commercial and business Housings and residential Factory/recreational Site/quarrying/waste and sewage/energy/landfill and port	• Efforts in responsible resource recycling and proper treatment of waste disposal Consideration of exterior wall materials and paints
QC	Transportation	• Greening structures including vacant lots, sidewalks, buffer zones, walls, *etc.* • Implementation of cool pavement with water retentiveness and ground surface covering to mitigate the thermal environment
	Canals, river and other	• Seawall with high permeability and planting to regenerate water circulation
	Commercial and business Housings and residential Factory/recreational	• Minimizing asphalt or concrete pavement • Implementation of pavement with better water retentiveness/Active greening • Use of architectural materials and paints in consideration of heat island effect
	Site/landfill and port	• Minimizing artificial surface coverings for better rainwater infiltration • Minimizing asphalt or concrete pavement • Implementation of pavement with better water retentiveness
	Waste and sewage/energy	• Minimizing asphalt or concrete pavement • Implementation of pavement with better water retentiveness / Active greening • Use of architectural materials and paints in consideration of heat island effect

4.4. Seoul

The 2030 Seoul Master Plan (2014) is a strategic plan focused mainly on five emerging issues. The Seoul Master Plan outlines the directions of supplementary plans in terms of the use, development and preservation of land. The master plan ranges over various disciplines, including society, economy, environment, energy, transportation, infrastructure, culture, and welfare. The city set up regional plans and guidelines to fill the gap between the master plan and the subordinate plans. The Safe City with Life Alive theme, one of the five main issues of the master plan, involves three objectives: creating an eco-city led by parks; realizing a resource circulation city with energy efficiency; and making a safe city. Each objective is implemented in the strategies. The material-related strategies are listed in Table 18. The specific measures, targets and detailed items are not covered in this master plan.

Table 18. Material-related objectives and strategies to achieve the theme of a safe city with life alive.

Objective	Strategy
Eco-city led by parks	• Reinforced Controllability of Urban Climate: Eco-friendly urban surfaces, mitigated heat island effect, climate change monitoring system • Preservation and recovery of natural ecology inside the city and improved functions for the public interest • Improved quality and optimization of urban living environment
Resource circulation city with energy efficiency	• Expansion of resource recycling

The Landscape Design Guideline Manual (2012) sets up targets and strategies according to the landscape type characteristics: Natural Green Landscape; Waterfront Landscape; Historic and Cultural Landscape; and Urban District Landscape. Generally, the sustainable requirements for landscape design are insufficiently described, except for greenery. Material-related strategies in this manual are related to a historical and cultural atmosphere and to a harmonization with historical resources and their unique features. Architectural materials should be considered for their quality to suit historical surroundings and their durability. Landscape Design Guideline and Checklist in the manual specifies the material qualities for each landscape zone, as shown in Table 19.

Urban Development Sustainable Building Environment Assessment Guideline (2011) applies to projects over the scale at the environment impact evaluation target, as an urban development project. The criteria for evaluation are organized in seven sections with 41 items, covering land use, transportation, energy, ecological environment, resource cycling, water cycling, and indoor environment. The material items include thermal insulation, environment-friendly architectural materials, recycled wastes, permeable pavement, and materials with low-emission of VOC and asbestos, as shown in Table 20. These are limited to building materials. Materials are recognized as a part of the surfaces and buildings in specific measures to achieve the goals of energy, water and indoor environment. The concept of materials as economic and social resources is not fully accepted in these guidelines, even though the landscape guideline focuses on these values.

Table 19. Material qualities specified in the landscape design guideline and checklist.

Zone	Material Qualities
Urban Core Landscape Zone Inner/Out Four Mountain Axis Base of Historical Characteristics	• Materials in harmony with surrounding landscape resources and regional features • Avoiding materials that stand out and disturb the harmony, such as luminous materials • For exterior space, use of natural materials and adoption of qualities and colors in harmony with surroundings • For outdoor advertising, use of materials in harmony with the building and surroundings
Waterfront Axis	• Bright and light materials • For the podium facing main streets, use of various materials to vitalize the streetscape
North-South Green Axis	• Use of soft materials in harmony with green landscape • Avoiding materials that stand out and disturb the harmony such as luminous, transparent, or reflective materials • For the podium facing main streets, use of various materials to vitalize the streetscape
Seoul City Wall Axis	• Use of natural and soft materials in harmony with Seoul City Wall • Use of materials considering the lapse of time embedded in Seoul City Wall • Use of natural materials, such as stone, brick and wood • Avoiding rapidly deteriorating materials • Avoiding materials that stand out and disturb the harmony such as luminous, transparent, reflective materials • Use of homogeneous roof materials with qualities and colors in harmony with Seoul City Wall in buildings visible from the wall

Table 20. Material criteria in the urban development sustainable building environment assessment guideline.

Sector	Items
Energy	• Thermal insulation
Resource Cycling	• Environment-friendly architectural materials • Recycling of wastes and reduction of wastes
Water Cycling	• Permeable pavement
Indoor Environment	• Materials with low-emission of VOC and asbestos

4.5. Discussion on the Urban Guidelines of London, New York, Tokyo and Seoul

From the examination of urban master plans and design guidelines, the general differences between Seoul and the other three cities, London, New York and Tokyo, can be outlined. The urban master plans and supplementary design guidelines of London, New York and Tokyo are interrelated in setting up design criteria, describing detailed requirements and specifying measures in infrastructure, landscape, and building materials. In addition, those documents are associated with neighborhood sustainability assessment tools in different ways. However, in Korea, there is no neighborhood sustainability assessment tool, which can be the basis for setting up detailed urban design guidelines. All of Seoul's top Master Plan and urban design guidelines, as well as the district-level master plans and guidelines, have inconsistent aims and sectors for sustainability assessments.

For a comparative analysis of the urban guidelines of each city with the neighborhood sustainability assessment tools, the proposed circle of sustainable materials was used as a study protocol. As shown in Figure 9, each guideline has different structures, features and considerations of the material requirements.

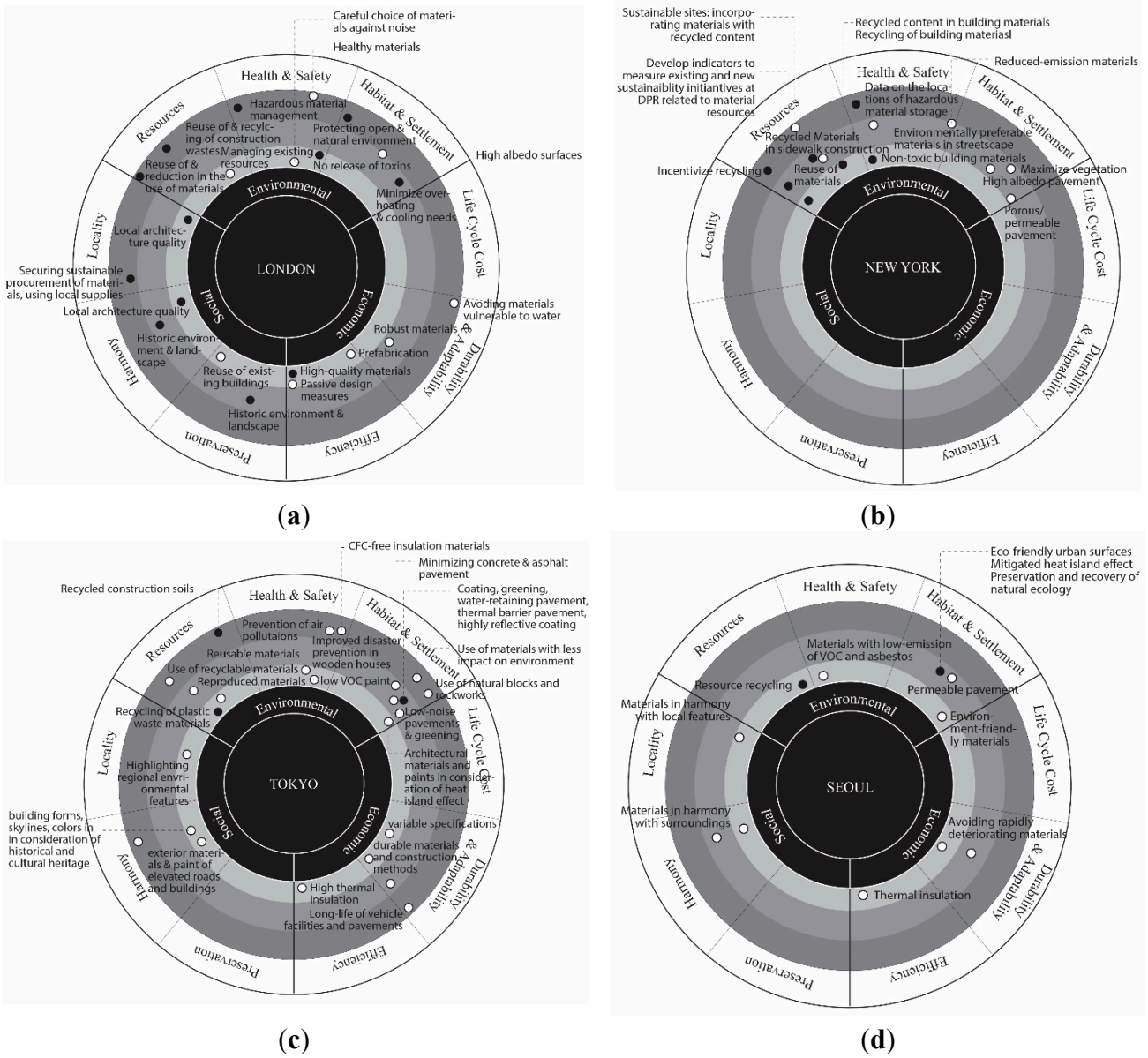


Figure 9. Urban design guidelines in circle of sustainable materials: (**a**) London; (**b**) New York; (**c**) Tokyo; and (**d**) Seoul (●: Top-level master plan; ○: Supplementary design guideline).

In the cases of London and New York, the top master plans include more detailed material criteria, compared to those of Tokyo and Seoul. Tokyo and Seoul have their top master plans focused towards their big city visions, without specifying the detailed criteria for materials. The material criteria included in the master plans of Tokyo and Seoul are Resources and Habitat and Settlement.

The London Plan covers many materials sustainability issues but there is no clear distinction of material uses in the infrastructure, landscape and building. The urban design guidelines of London involve more sustainability issues in Habitat and Settlement, Locality and Harmony than the BREEAM Communities. PlaNYC emphasizes Resources and Health and Safety, while supplementary guidelines involve more criteria in Habitat and Settlement in addition to Resources and Health and Safety. The urban design guidelines deal with only the environmental issues in materials, whereas the LEED-ND assesses Preservation and Durability and Adaptability. From a balanced view of sustainability, the New

York urban design guidelines are heavily weighted towards environmental issues. Among the urban design guidelines, the material techniques and specifications are described in the most detail.

Although the City Planning Vision only focuses on these issues, the other design guidelines cover most issues in detail, except for the Preservation and Life-Cycle Cost. Tokyo's urban design guidelines specify the material requirements according to the regions and project types, as well as the material requirements at different scales of urban design. Although CASBEE-UD includes Preservation, the Tokyo urban guidelines do not have any items as a preservation strategy.

Seoul has the least sustainable materials items in its urban guidelines. In addition, compared to other guidelines, the urban design does not include the material selection and infrastructure uses. Although the top master plan targets resource recycling, the supplementary guidelines do not include any strategies or measures to develop and implement resource recycling. Many building materials issues were approached, but they were not specified in detail.

In summary, London and New York have detailed material criteria in their top master plans, whereas Tokyo has supplementary urban design guidelines that specify most material sustainability issues. The differences in material items and priorities among the four cities can be reasoned from an analysis of the validity of the assessment tools in the city planning policy, in such cases, the relationship between the assessment tools and the urban design guidelines and regional concerns on the urban settings and the stages of development. For instance, in London and New York, regeneration and redevelopment issues might be of more concern, while in Tokyo, expansion of the urban area and new developments might be the main focus. The relationship between the assessment tools and the urban design guidelines of the three cities is discussed further in Section 5.

5. Comparison of Neighborhood Sustainability Assessment Tools and Urban Design Guidelines

Neighborhood sustainability assessment tools are still quite new. The urban design guidelines, methods and tools specifically designed to provide integrated attention to sustainability concerns are not yet well developed [23].

BREEAM Communities, LEED-ND and CASBEE-UD are globally accepted neighborhood sustainability assessment tools. The comparison between these tools and urban design guidelines demonstrates the city policy direction in applying these tools to their regulations, standards and guidelines.

In the UK, the requirements of sustainability assessment tools, including BREEAM, the use of renewable energy, and other sustainability measures and indicators are variably accepted by city authorities. The London Plan sets energy requirements for new development as well as requirements for building materials, waste management and water efficiency. BREEAM can be used to address all of the required issues by the governments. As demonstrated in Table 21, both BREEAM Communities and the urban design guidelines of London require reuse and recycling, low-impact materials, and durable materials in infrastructure. Buildings made of materials that are low-impact, low-emission, and free of toxins are common requirements in BREEAM Communities and in the urban design guidelines of London. For infrastructure and landscape, many material indicators are shown either in BREEAM Communities or in urban design guidelines. For building materials, urban design guidelines are more stringent, particularly in economic and social categories. In this case, BREEAM Communities and the urban design guidelines should supplement each other to select materials for more balanced sustainability.

Table 21. Comparison of BREEAM communities and urban design guidelines of London. (●: matching; ○: possible).

Category	Indicator	Item	Infrastructure		Landscape		Building	
			BREEAM Communities	London	BREEAM Communities	London	BREEAM Communities	London
Environmental	Resources	Reuse and recycling	●	●	●		●	
		Low-impact materials	●	●	●		●	●
	Health and Safety	Low emission		●			●	●
		Waste reduction	●		●		●	
		Non-toxic materials		●			●	●
		No pollutants	●	●				
		Disaster prevention						
	Habitat and Settlement	Low impact on nature				●	○	
		Protection		●				
Economic	Life-Cycle Cost	Life-cycle impact reduction						
	Durability and Adaptability	Durable materials	●	●	●	●		
		Flexibility						
	Efficiency	Low material demands	●		●			●
		Low embodied energy						●
Social	Locality	Locally supplied materials	●					
		Locally produced materials						●
	Harmony	Regional context				●		●
	Preservation	Reuse of existing built form	●			●	●	●

In the case of LEED-ND and the urban design guidelines of New York, LEED-ND satisfies more indicators with an apparent excess in building materials in Table 22. Local Law 86 [56] requires construction work managed through city agencies as well as through non-city entities, such as cultural organizations, state agencies, and private developers, to achieve minimum LEED rating levels. Therefore, building material requirements might be considered to be controlled and mandated by LEED. This approach is similar to the way LEED-ND covers building material requirements by prescribing green certified buildings.

The relationship between CASBEE-UD and Tokyo is different from the previous comparisons. From Table 23, reuse and recycling and regional context for harmony in infrastructure are shown both in CASBEE-UD and in urban design guidelines. Low-impact materials and materials for mitigation of impact on nature and protection in landscape materials are commonly required in CASBEE-UD and in urban design guidelines. For building materials, CASBEE-UD allows the consideration of health and safety as well as habitat and settlement by item. "Environmentally friendly buildings," which evaluates the level of effort for the CASBEE assessment (New Construction, Detached House, or Property) on the block, is similar to the LEED-ND's "green certified buildings". Urban design guidelines of Tokyo cover more indicators in infrastructure materials and building materials than CASBEE-UD covers, as demonstrated in Table 23. As the Tokyo metropolitan government does not use CASBEE-UD, but operates its own assessment system, urban design guidelines might prescribe equal or more items of infrastructure, landscape and building materials and describe more details on the sustainable performance of materials.

Table 22. Comparison of LEED-ND and urban design guidelines of New York. (●: matching; ○: possible).

Category	Indicator	Item	Infrastructure		Landscape		Building	
			LEED ND	New York	LEED ND	New York	LEED ND	New York
Environmental	Resources	Reuse and recycling	●	●		●	●	●
		Low-impact materials					○	
	Health and Safety	Low emission				●	○	
		Reduction of waste					○	
		Non-toxic materials		●			○	●
		No pollutants	○					
		Disaster prevention						
	Habitat and Settlement	Low impact on nature	●		●	●	●	
		Protection				●		
Economic	Life-Cycle Cost	Life-cycle impact reduction					○	
	Durability and Adaptability	Durable materials						
		Flexibility	●		●		●	
	Efficiency	Low material demands						
		Low embodied energy						
Social	Locality	Locally supplied materials						
		Locally produced materials						
	Harmony	Regional context						
	Preservation	Reuse of existing built form	●		●		●	

Table 23. Comparison of CASBEE-UD and urban design guidelines of Tokyo. (●: matching; ○: possible).

Category	Indicator	Item	Infrastructure		Landscape		Building	
			CASBEE UD	Tokyo	CASBEE UD	Tokyo	CASBEE UD	Tokyo
Environmental	Resources	Reuse and recycling	●	●	●		●	●
		Low-impact materials	●		●	●	●	
	Health and Safety	Low emission		●			○	●
		Reduction of waste					○	
		Non-toxic materials					○	
		No pollutants		●			○	
		Disaster prevention						●
	Habitat and Settlement	Low impact on nature		●	●	●	○	●
		Protection		●	●	●		
Economic	Life-Cycle Cost	Life-cycle impact reduction						
	Durability and Adaptability	Durable materials	●	●		●		●
		Flexibility						
	Efficiency	Low material demands						
		Low embodied energy						●
Social	Locality	Locally supplied materials						
		Locally produced materials						●
	Harmony	Regional context	●	●	●		●	●
	Preservation	Reuse of existing built form	●				●	

Cross-evaluation of neighborhood sustainability assessment tools and urban design guidelines reveals a difference in coverage of indicators in London, New York and Tokyo. The implementation and application of neighborhood sustainability assessment tools by the city government determines the approach and measures for sustainable materials, as well as the level of detail in the urban design guidelines. In addition, local issues included in the global sustainability assessment tools are treated in urban design guidelines. These indicators include disaster prevention materials, locally supplied or produced materials, and materials in consideration of the regional context.

There are studies [22,57,58] with the objective to propose regional sustainability assessment tools suitable for the context-specific conditions of a region. The regional neighborhood sustainability assessment tools can be helpful for urban planners, public administrations, developers and architects involved in urban development projects. The reality of cities can vary depending on factors such as, location, weather conditions, and socio-economic context. Thus, not all tools are valid in all regions of the world. Therefore, formulated tools must exist that adapt to the context, planning, population, and cultures and traditions, of a given environment [22]. The scope of environmental management as a multi-professional activity has become so vast that it is difficult to measure the impact of regional efforts on an international scale. Implementation of international guidelines at the local level faces problems of political, administrative, social, environmental and educational natures [58].

As reviewed previously, Seoul has relatively loose urban design guidelines that do not lead to balanced sustainability of materials of urban settings. The drawbacks of Seoul's urban design guidelines might be overcome by either the development of regional neighborhood sustainability assessment tools, including categories of sustainable materials, or the detailed inclusion of material requirements in urban design guidelines. The current global assessment tools, including BREEAM Communities, LEED-ND and CASEE-UD, may be utilized in the development of regional neighborhood sustainability assessment tools, which emphasize local characteristics. In the development of a regional assessment tool, the structure of the urban assessment tools and the coverage of the criteria and the indicators must be reflected in the local context [4].

6. Conclusions

In this paper, the circle of sustainable materials is proposed as a framework for a comparative analysis of neighborhood sustainability assessment tools, and the urban design guidelines of London, New York, Tokyo, and Seoul. In the circle of sustainable materials, the evaluation criteria include three major categories, environment, economy and society, to embrace the concept of sustainability. To cover all of the material elements that are available in urban developments, the materials are categorized into building materials, landscape materials and infrastructure materials. An overview of the material criteria in neighborhood sustainability assessment tools and urban planning guidelines was discussed to summarize the current system's features and weaknesses as a balanced material assessment for sustainable urban development.

All neighborhood sustainability assessment tools, BREEAM Communities; LEED-ND; and CASBEE-UD, evaluate the Resources, Preservation and Durability and Adaptability for sustainable materials. Although there are differences in the levels and strategies in assessing other sustainability

issues of materials, all of the tools pursue a balanced concept of sustainable materials in the environment, economy and society.

All urban design guidelines for London, New York and Tokyo interrelate with neighborhood sustainability assessment tools for the shared directions and strategies of sustainable materials. However, guidelines have more specific and more varied measures than global tools. In the case of Seoul, without a neighborhood sustainability assessment tool, the urban guidelines are less developed than the others. In addition, the design guidelines structure, detailed material requirements and approach to different scales varies depending on the city.

The concept of life-cycle cost appears difficult to incorporate in neighborhood sustainability assessment tools and urban design guidelines. Although preservation is a commonly shared item in the assessment tools, it is not necessarily required in the urban design guidelines of the discussed cities. The ideas of preservation and life-cycle cost in material assessments and requirements should be studied further in order to achieve sustainability in material implementations of urban development.

Comparison of neighborhood sustainability assessment tools and urban design guidelines provided lessons for the initiation of future urban design guidelines and a sustainability assessment tool for the city of Seoul. The relationship between the urban design guidelines and the neighborhood sustainability assessment tools should be defined in the city policy to determine the direction of the guidelines and assessment tools and to require more meticulous details of material criteria in the urban design guidelines by regularizing the sustainability assessment.

The findings of this research provide several insights for further study. Concerning the assessment of sustainable materials in Seoul, the value and concept of sustainability from the local perspective should be further discussed. In addition, an assessment system of sustainability materials could be proposed to integrate into the local urban design guidelines.

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Author Contributions

All of the authors contributed equally to this work. All authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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