True Smart and Green City?
8th Conference of the
International Forum on Urbanism

Conference Proceedings Paper

Comparative Analysis of Material Criteria in Green Certification Rating Systems and Urban Design Guidelines

Jungwon Yoon [1]*, and Jiyoung Park [2]*

[1] University of Seoul, Department of Architecture, 163 Seoulsiripdae-ro, Dongdaemun-gu, Seoul 130-743, Korea
[2] Inha University, Department of Architecture, Inharo 100, Nam-gu, Incheon 402-751, Korea

E-Mails: jwyoon@uos.ac.kr (Jungwon Yoon); jypark@inha.ac.kr (Jiyoung Park)

* Author to whom correspondence should be addressed; Tel.: +82-2-6490-2784; Fax: +82-2-6490-2749 (jwyoon@uos.ac.kr)

Received: / Accepted: / Published:

Abstract: Green certification rating systems have been developed for building-scale sustainability since 1990s, and several systems such as BREEAM, LEED and CASBEE are widely used. They have kept upgraded and recently adapted to the large-scale development. BREEAM Communities, LEED Neighborhood Development and CASBEE for Urban Development are examples implemented respectively in UK, USA and Japan. Also, as the notion of green urban design gains more significance, city governments have set its own green standards in urban design guidelines, based upon studies of green certification rating systems. This paper focuses on comparative analysis of material criteria embedded for sustainable urban design in BREEAM Communities, LEED ND and CASBEE UD with urban design guidelines recently issued for multiple cities including London, New York, Tokyo and Seoul. The paper examines differences of material assessment criteria, evaluation parameters, and descriptions in green certification rating systems and urban design guidelines. Materials are categorized into: (1) building (2) infrastructure (3) landscape. In analysis of urban design guidelines, the top master plans are overviewed in addition to the supplementary guidelines for investigation of detailed material criteria. In conclusion, overview of investigated material criteria is discussed to summarize current features and weakness as balanced material assessments for the sustainable urban development

Keywords: Material; Green Certification Rating System; Sustainable Urban Development; BREEAM Communities; LEED-ND; CASBEE-UD; Urban Design Guideline

---

1. Introduction

More countries make efforts to introduce and develop green cities and subsequently, administrative governments and policy councils are involved in setting up tools and guidelines to accelerate formation of sustainable urban neighborhoods and implement green city planning and development. Among various systems dedicated to assess, guide and regulate the sustainable approach in architecture and urban planning, the green certification rating systems have been considered as reliable and meaningful tools to achieve the goal of sustainability. In many leading countries, green certification rating systems for building-scale sustainability have been established since 1990s. They have endlessly updated and applied into multiple range of projects in different types and scales. The most widely applied examples are BREEAM (Building the Research Establishment Environmental Assessment Method) in UK, LEED (Leadership in Energy and Environmental Development) in USA, and CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan. These systems were divided into many specialties including neighborhood development and city planning: BREEAM Communities, LEED ND, and CASBEE UD.

These systems are assessment tools to indicate the level of achieving sustainability in design process, implementation and operation of a neighborhood development project. They are not mandatory programs for all of developments, rather voluntary preferential tools applied by the project initiators. These schemes cannot control and regulate the design and planning strategies unless otherwise directed by the governments. Therefore, to imply the sustainable urban design standards and strategies in current and future projects, a number of city authorities endeavor to integrate items and criteria of green certification rating systems in their urban design guidelines after conducting researches and studies.

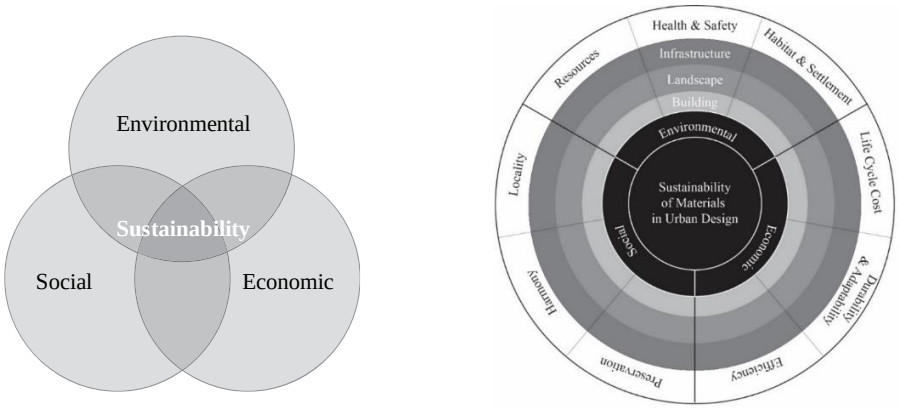
All of rating systems and green urban design guidelines are differently organized and classify evaluation items. Nevertheless generally site, transportation, energy, water, atmosphere, and resources are major elements targeted in sustainable design. Among those, energy has been highly recognized in numerous studies and project executions. Recently, resources raise attentions in approaching various issues on material life-cycle impacts, natural resource depletion, pollution, health and physical materialization tools for other environment-friendly strategies for energy, water and atmosphere. Especially for urban designers, landscape designers and architects, materials are the main subject to deal with environmental problems as well as their design principles and disciplines. From this view, the paper focuses on material assessment criteria in green certification rating systems and descriptive standards on materials in urban design guidelines.

The paper is organized as follows: Section 2 identifies and compares material criteria in green certification rating systems including BREEAM Communities, LEED ND and CASBEE UD. In the analysis, the concept of three legs of sustainability is adopted. Section 3 outlines material requirements in urban design guidelines of New York, London, Tokyo and Seoul, and compares the material criteria for building, infrastructure and landscape of all the guidelines with the previously discussed green certification rating systems.

2. Material Criteria in Green Certification Rating Systems: BREEAM Communities, LEED Neighborhood Development and CASBEE for Urban Development

2.1. Framework of Sustainable Material Assessment: the Circle of Sustainable Materials. For a holistic and inter-discipline approach, sustainability addresses aspects of environment, social, and economic as shown in The Circle of Sustainability (Figure 1. (a)).[1] It is mostly used for cities and urban settlements, by a series of global organizations. It helps understanding sustainable urban design which ensure to provide social and economic benefits while mitigate the environmental impacts of the built environment. Also, this concept is applicable to sustainable material assessment. For instance, materials assessment database and systems like Pharos adopted thus concept with partial adjustment; Pharos lens is organized in (1) Environmental · Resources; (2) Social · Community; (3) Health · Pollution, instead of Economic.[2,3]

Figure 1. (a) The Circle of Sustainability: Three Legs of Sustainability
(b) The Circle of Sustainable Materials: Based on Three Legs of Sustainability



(a) **(b)**

This paper proposes "The Circle of Sustainable Materials" to integrate the most generic and comprehensive concept to approach sustainability assessment as presented in Figure 1. (b). with following principles:

- Each sphere includes three indicators to cover environmental, economic, and social issues in an equal attitude.
- Indicators are proposed based upon some concepts in Pharos Lens, Building Materials and Furnishings Sustainability Assessment Standards by the Whole Building Design Guide[4], and University of Michigan Sustainability Assessment[5], and Ten Shades of Green[6] to cover common values of green materials.
- Environmental indicators include: Resources, Health & Safety, and Habitat & Settlement.
- Economic indicators include: Life Cycle Cost, Durability & Adaptability, and Efficiency.
- Social indicators include: Locality, Harmony, and Preservation.
- Each Indicator can be assessed in different uses of materials applied in urban designs. The material application sphere can be categorized into: (1) infrastructure, (2) landscape and (3) building.

2.2. Analysis of Material Criteria in BREEAM Communities, LEED ND and CASBEE UD

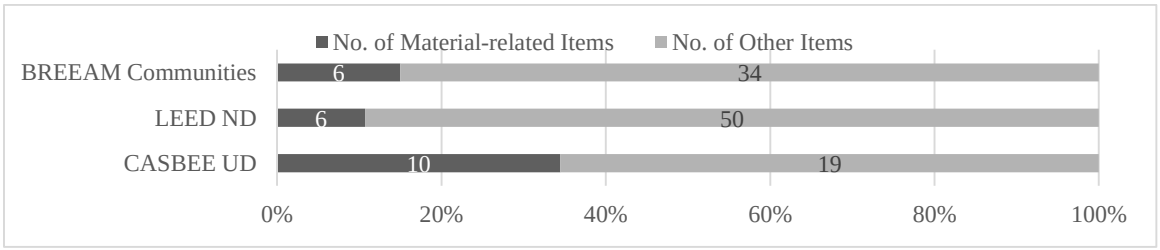
This section examines differences of material assessment criteria, evaluation parameters and methods, descriptions in green certification rating systems. BREEAM Communities, LEED ND and CASBEE UD adopt different assessment criteria. Assessment criteria in BREEAM Communities are grouped into five categories, which are considered in three steps from step 1 establishing the principles, step 2 determining the layout to step 3 designing the details. [7] The LEED for ND addresses five topics.[8] CASBEE UD has classifications of environment, society, and economy as major criteria of assessment by adopting the Three Legs of Sustainability in its structure.[9]

As shown in Table 1, BREEAM Communities and LEED ND include more classification of minor items than CASBEE UD. As a result of analysis of detailed description of minor items related to materials, each green certification system shows a different weight on materials in evaluating sustainability of urban design and development depending on its assessment criteria. In BREEAM Communities, material items are included in Resources and Energy, and Transport and Movement. In LEED ND, material items are included only in Green Infrastructure and Buildings. In CASBEE UD, material items are covered in all of classifications of environment, society and economy. In major criteria, Environment: Resource, Environment: Nature, Environment: Artifact, Social: Amenity, and Economy: Efficiency/Rationality have minor items regarding materials. As Figure 2 shows, CASBEE UD has the highest ratio of material assessment items in its rating system compared to LEED ND and BREEAM Communities.

Table 1. Assessment Criteria of BREEAM Communities, LEED ND and CASBEE UD
(Q means quantity of minor items. Note that this number is not equal to available credits for each item)
(Grey Shade indicates assessment criteria relevant to sustainable materials) (In LEED ND, P : Prerequisite, C : Credit)

Green Certification System	**BREEAM Communities**		**LEED ND**		**CASBEE UD**	
	Categories	Q	Categories	Q	Categories	Q
Assessment Criteria	Governance	4	Smart Location and Linkage	14 (P5, C9)	Environment: Resource	4
	Social and economic wellbeing	17			Environment: Nature	4
	Resources and Energy	7	Neighborhood Pattern and Design	18 (P3, C15)	Environment: Artifact	1
	Land Use and Ecology	6	Green Infrastructure and Buildings	21 (P4, C17)	Social: Impartiality / Fairness	2
					Social: Safety/Security	4
					Social: Amenity	4
	Transport and Movement	6	Innovation and Design Process	2 (C2)	Economy: Traffic/Urban structure	4
					Economy: Growth potential	3
			Regional Priority Credit	1 (C1)	Economy: Efficiency/Rationality	3
No. of Items	5	40	5	56 (P12, C44)	3(9)	29
No. of Minor Items related to material	6		6		10	

Figure 2. Comparison of Ratio of Material Criteria in Assessment of Urban Development Sustainability



For comparative analysis of detailed items, the previously proposed circle of sustainable materials is adopted as a tool in Table 2. BREEAM Communities specifies low impact materials, sustainable

buildings and resource efficiency to drive healthy, safe and habitable communities and environment. Its unique item is specification of shelter seating materials at public transport facilities to be durable.

LEED ND values in recycled content in infrastructure as well as solid waste management infrastructure. In addition, it specifies materials with SRI higher than 29 to mitigate heat island effects. Regional Priority criteria would be possible to be used to evaluate locality of materials in urban development, although current details don't include use of the local and regional materials.

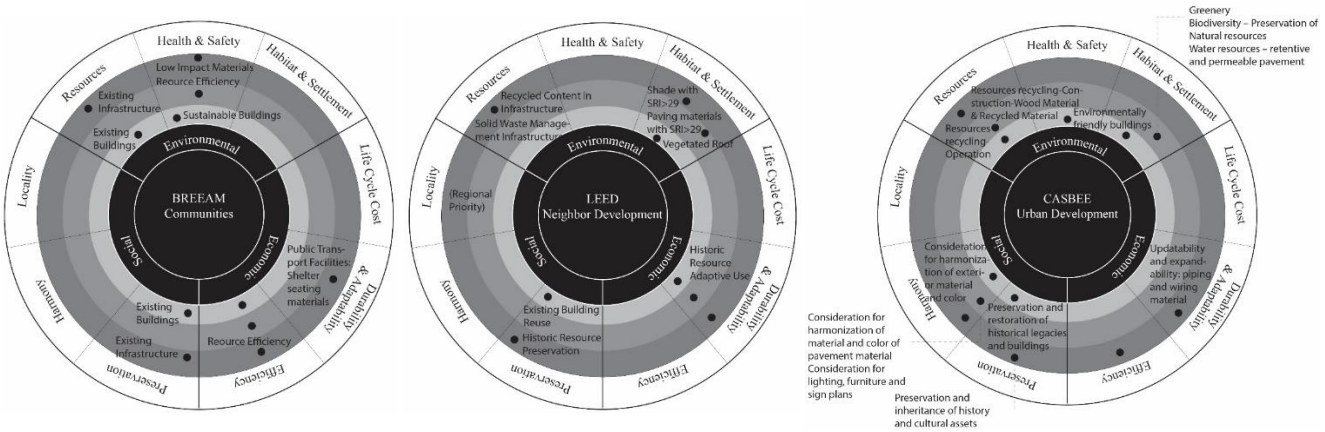
CASBEE UD covers almost all criteria of the circle of sustainable materials except Life Cycle Cost and Locality, which are not included in any analyzed rating systems, although it is considered as an important concept in sustainable material standards. It assesses materials of landscape such as pavement, street furniture, lighting and signs for environmental habitat and settlement, and social harmony. In prescribing recycling, it tends to be more specific on materials types in consideration of local resources.

Table 2. Material Criteria in Green Certification Rating Systems
(Dark grey shade indicates infrastructure, Medium grey shade indicates landscape, and blank shade indicates buildings and all.)

Part	Criteria	BREEAM Communities	LEED ND	CASBEE UD
Environmental	**Resources**	Existing Infrastructure	Recycled Content in Infrastructure Solid Waste Management Infrastructure	Resources recycling-Construction-Wood Material
				Resources recycling-Construction- Recycled Material
		Existing Buildings		Resources recycling-Operation
	Health & Safety	Low Impact Materials	-	Environmentally friendly buildings
		Sustainable Buildings		
		Resource Efficiency		
	Habitat & Settlement	Sustainable Buildings	Shade with SRI>29	Greenery Biodiversity – Preservation of Natural resources
			Paving materials with SRI>29	Water resources – retentive and permeable pavement
			Vegetated roof	Environmentally friendly buildings
Economic	**Life Cycle Cost**	-	-	-
	Durability & Adaptability	Public Transport Facilities: Shelter seating materials	Historic Resource Adaptive Use	Updatability and expandability: piping and wiring material
	Efficiency	Resource Efficiency		
Social	**Preservation**	Existing Infrastructure	Historic Resource Preservation	Preservation and inheritance of history and cultural assets
		Existing Buildings	Existing Building Reuse	Preservation and restoration of historical legacies and buildings
	Harmony	-	-	Consideration for harmonization of material and color of pavement material
				Consideration for lighting, furniture and sign plans
				Consideration for harmonization of exterior material and color
	Locality	-	(Regional Priority)	-

In Figure 3, all of rating systems cover the three spheres of sustainability, but BREEAM Communities and LEED ND tend to focus on more on reuse of existing infrastructure and buildings, achieving environmental resources and social preservation. CASBEE UD approaches materials as resources to be saved and recycled but also as factors attributing other environmental sustainability and harmonized urban structure.

Figure 3. Circles of Sustainable Materials **(a)** BREEAM Communities. **(b)** LEED ND. **(c)** CASBEE UD



(a) **(b)** **(c)**

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

This chapter focuses on analysis of material criteria and requirements in urban design guidelines recently issued in major cities such as London, New York, Tokyo and Seoul. Also, they will be compared with s the green certification rating systems. Among many guidelines and standards by each municipality, we looked at the top master plan setting up the future vision and directions of city planning as well as supplementary guidelines for environment, landscape and infrastructure depending on availability according to the urban guideline structure by each municipality.

3.1. London

The Greater London Authority (GLA) published the first London Plan in 2004 as the spatial development strategy (SDS) focusing on sustainability and spatial plan. As circumstances change such as economy and population growth, the London Plan has kept altered or, if necessary, replaced. Under the legislation of GLA Act 1999, the London Plan take account of three cross-cutting themes: economic, social, environmental. Then, it sets out a fully integrated framework of three legs of sustainability for the development of the capital over the next 20-25 years. It forms part of the development plan for Greater London. 32 London boroughs' local plans need to be in general conformity with the London Plan, and its policies guide decisions on planning applications by councils and the Mayor[10].

The latest London Plan (2015) is composed by eight chapters: Context and strategy, Places, People, Economy, Response to climate change, Transport, Living places and spaces, Implementation, Monitoring and review. The figure 4 shows ratio of material-related policies in each categories of the London Plan. Among total 121 policies, there are eleven material-related policies: six polices in Response to Climate Change and five polices in Living Spaces and Places.

Figure 4. Ratio of Material-related policies in the London Plan (2015)

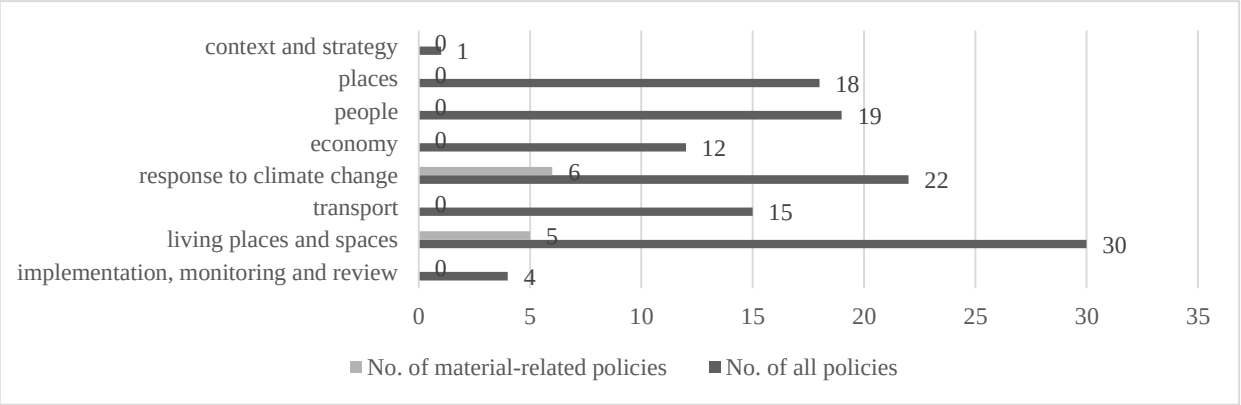


Table 3 shows the eleven material-related policies with their description. They cover the broad spectrum of sustainable material such locality, reuse and recycling, reduction, waste, health, pollution, and high performance. In consequence, it covers all of economic, social, environmental issues[11]. Since the London Plan is the overall city plan, it does not describe the detailed strategies.

Table 3. A List of 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 meet its cooling needs
	Waste	5.16 Waste net self-sufficiency	encouraging the reuse of 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	re-use 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 building	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 toxics
	Protecting open and natural environment	7.19 Biodiversity and access to nature	positive gains for nature through materials

The Supplementary Planning Guidance (SPG) provides further detail on particular policies in London Plan. 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. It composed three chapters: Resource management, Adapting to climate change and greening the city, Pollution management (land, air, noise, light and water). Though various material-related practice are introduced in multiple chapters, majorly, chapter 2.7 Material and Waste provides guidance by phases in detail as shown in Table 4[12].

Table 4. A List of material-related items in 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	
			the waste hierarchy	
			historic material	
		Occupation	storage for recyclables, organic, material and waste	
Adapting to climate change and greening the city	3.2 Tacking 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 floor 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	

3.2. New York

The City of New York released PlaNYC in 2007 to address its long-term challenges including the forecast of 9.1 million residents by 2030, changing climate conditions, an evolving economy, and aging infrastructure. It is the comprehensive sustainability plan for a greener, greater New York[13]. The City has updated PlaNYC every four years, with the next update due out in 2015. Also from 2007, the Progress Report has been published for monitoring PlaNYC, and the sixth progress report was published in 2014[14]. The latest version of PlaNYC (2011) launched 127 initiatives in ten categories: Housing and neighborhoods, Parks and public space, Brownfields, Waterways, Water supply, Transportation, Energy, Air quality, Solid waste, and Climate change. Some of initiatives are related into materials, but the major issue is about managing waste in the city rather than about design and construction materials as shown in Table 5[15].

Figure 5. Ratio of Material-related policies in the PlaNYC (2011)

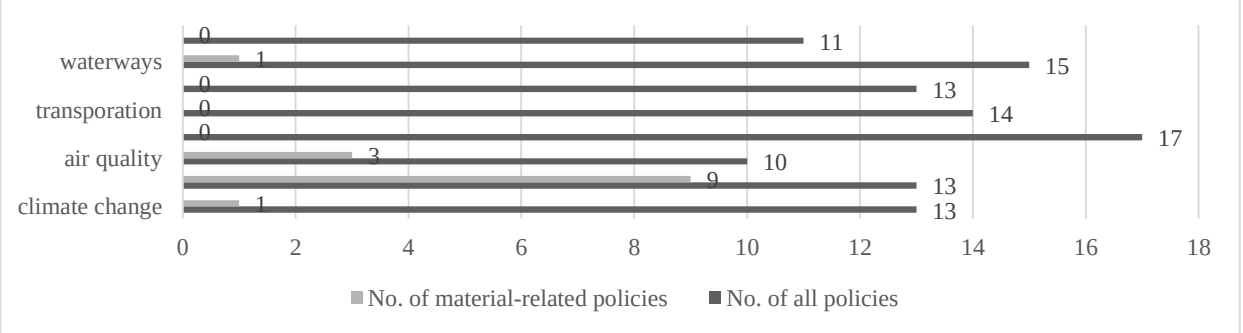


Table 5. A List of material-related items in PlaNYC (2011)

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 stormwater	9. Modify codes to increase the capture of stormwater	increase recycled materials within all new sidewalk construction.
Air Quality	Update codes and standards	9. Update our codes and regulations to improve indoor air quality	propose regulations to reduce exposure to toxics released by building materials
Solid Waste	Reduce waste	2. Increase the reuse of materials	to 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 efficiency of 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 the access to publicly available data on the locations of hazardous material storage in flood zones throughout the city

All city projects should be informed by PlaNYC. To guide the sustainable development of publicly-owned property, the Department of Design and Constructions (DDC) issued several design manuals with more detailed information.

The High Performance Infrastructure Guidelines (2005) was published after the High Performance Building Guidelines (1999) to manage design and construction of streetscape and public right of way projects. Infrastructure Division of DDC worked on this in partnership with The Design Trust for Public Space, which is non-profit organization. Then, this is more about design and construction rather than overall city plan. It focuses on the seven dimensions: Site Assessment, Streetscape, Pavement, Utilities, Stormwater management, Landscape, and Construction practices. And, this presents the fifty three 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 of three dimensions are related into material as shown in Table 6. It provides the specification of materials to achieve with references and introduce examples in NYC as the precedents[16].

Table 6. A List of material-related items in 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 Biobased Filter Fabric
	PA.6. Use Recycled and Reclaimed Materials	Develop a recycled and reclaimed materials program
		Applications in asphalt concrete
		Applications in 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

Also the Department of Design and Constructions (DDC) of New York City published the Sustainable Urban Site Design Manual (2008), which has different scope with the High Performance Infrastructure Guidelines (2005). It is developed by Structure Division. It addresses landscape opportunities associated with building projects and offers an introduction to more environmentally, economically, and socially responsible urban site design practices for New York City capital projects. It has four topics : Maximize vegetation, Minimize site disturbance, Water management on urban sites, Materials in Site & Landscape Design. Each topic focuses on practical recommendations and marries the unique site conditions encountered on many city projects with appropriate sustainable site design strategies. Also, it highlights applicable LEED strategies as well as local laws, rules and regulations. Particularly, the chapter for Materials in Site & Landscape Design specifies environmentally preferable materials. It focuses on strategies for incorporation recycled materials in site features and construction[17].

Table 7. A List of material-related measures in the Sustainable Urban Site Design Manual (2008)

Chapter	Strategy	Specific techniques and descriptions
Water Management on Urban Sites	Strormwater Management	Hardscape techniques - porous pavements/ permeable pavers
Materials in Site & Landscape Design	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
	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

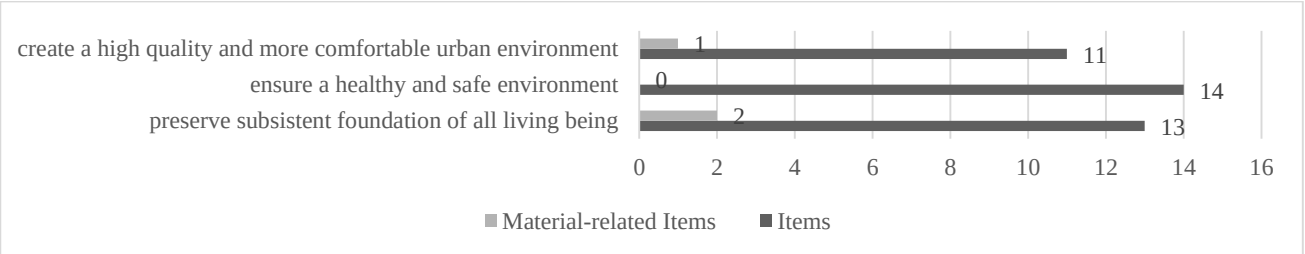
3.3. Tokyo

Bureau of Urban Development established the City Planning Vision for Tokyo (2001, Rev.2009). It sets the future vision of city and presents the strategic directions of urban policy. It 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.[18] Master Plan for City Planning Areas defines the future vision of the city and serves as the foundation for drafting individual city plans as obligatory.[19] Reinforced network between water and greenery and realization of the city coexisting with the environment are main themes in the agenda to create a rich urban environment.[20]

As parallel to the Master Plan for City Planning, Bureau of Environment sets up Tokyo Metropolitan Environmental Master Plan (2008), and Guidelines for consideration regarding urban planning (2008).[21] The Tokyo Metropolitan Environmental Master Plan aims to promote commitment to climate change, increase and conservation of green areas in the city, recycled use of resources, a better air quality, and a solution to negative legacy of the environment, including soil contamination. The Plan lists measures under three major sectors, organized as: Creation of a high quality and more comfortable urban environment (QC); Ensuring a healthy and safe environment (HS); Preservation of subsistent foundation of all living being (PF).

Figure 6. Ratio of Material-related items in the Tokyo Metropolitan Environmental Master Plan.



To preserve subsistent foundation of all living being, conservation and recycling of resources is promoted in the direction of reducing waste and promoting recycling, and of promoting sound waste processing and developing recycling business. In this direction, the targets are: To reduce the amount of final waste treatment; To eliminate the disposal of plastic waste to landfills by promoting the recycling of plastic waste materials; To increase the use of recycled construction soils; To create a mechanism that enhances that market value of excellent industrial waste processing companies.

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

Guidelines for consideration regarding urban planning aims to present the items for urban planning that private and public companies should consider at the phase of planning and implementation. It functions as a checklist to assess the environmental system. And it is organized in three parts: common items for consideration applicable to the urban planning, major items considered on the basis of regional characteristics of each zone of Tokyo and major items for consideration on the basis of each characteristic of the various operations involving urban planning.[21] The city is zoned as: 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 guideline maintains three sectors as the Tokyo Metropolitan Environmental Master Plan has. Required material approaches are more specific and detailed than CASBEE UD, while covering most items in CASBEE UD and differentiating values of items according to the regional and operational characters. Table 8 shows material-related consideration items in three parts categorizing basic environmentally friendly items and detailed considerations and approaches in urban development.

Table 8. A List of material-related measures in Guidelines for consideration regarding urban planning.

Part	Sector	Common consideration item		Approach
Common items for consideration regarding urban planning	PF	Prevention of generating waste & 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 at the 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 & VOC Prevention of scattering asbestos	Measures to prevent impacts on the surroundings by 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 and optimal shatterproof 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 and to reduce environmental risk
	QC	Mitigation of heat island effect	Greening Covering measures Attention to the wind corridor	Greening of artificial ground, green wall, and spaces Pavement types, pavement materials with high water retentivity 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 as well as colors.

Table 8. *Cont.*

Sector		Zone	Items	
Consideration on the basis of regional characteristics of zones	Regional	CCR	Redevelopment and refurbishment to highlight the regional environmental features Measures against surface coverings with pavements, buildings and asphalts causing increased heat and energy use. City planning and architecture in consideration of microclimate and thermal environment Environmental improvement of sufficiently utilizing the regional characteristics	
		UER	Improvement of disaster prevention at the dense residential areas with wooden houses	
	PF	CCR	Prevention of generating waste & promotion of recycling of waste	
		TBW		
	HS	CCR	Reduction of environmental risk caused by chemicals, soil pollution and water pollution	
		TBW		
		SCC	Prevention and reduction of air pollution	Measures to prevent impacts on the surroundings by 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

Sector		Operations	Items
Consideration on the basis of various operations	PF	Transportation Canals, river and other	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 of recycling ratio of materials and reduction of waste
		Commercial and Business Housings and Residential Factory / Recreational	High thermal insulation / Use of CFC-free insulation material Separated collection of insulation materials with Freon during demolition of a building for reduction of greenhouse gas Use of reproduced or recyclable materials such as recycled crushed stone Use of materials with less impact on the environment Improvement of recycling ratio of materials and reduction of waste
		Site / Landfill & Port / Quarrying	Reduction of volume, construction by-product by reuse and recycling
		Waste & Sewage treatment Energy Supply	Use of CFC-free insulation material Separated collection of insulation materials with Freon during demolition of a building for reduction of greenhouse gas Use of reproduced or recyclable materials such as recycled crushed stone Use of materials with less impact on the environment Long use of buildings with long-term life to save resources and reduce wastes
	HS	Transportation	Reduction of emission of NOx, SPM 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 & Sewage / Energy / Landfill & Port	Efforts in resource recycling and proper treatment of waste disposal with responsibility Consideration of exterior wall materials and paints
	QC	Transportation	Greening structures including vacant lots, sidewalks, buffer zones, walls and etc. Implementation of cool pavement with water retentivity 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 the pavement in asphalt or concrete Implementation of pavement with water retentivity / Active greening Use of architectural materials and paints in consideration of heat island effect
		Site / Landfill & Port	Minimizing artificial surface coverings for better rainwater infiltration Minimizing the pavement in asphalt or concrete Implementation of pavement with water retentivity
		Waste & Sewage / Energy	Minimizing the pavement in asphalt or concrete Implementation of pavement with water retentivity / Active Greening Use of architectural materials and paints in consideration of heat island effect

3.4. Seoul

2030 Seoul Master Plan (2014) is a strategic plan mainly focusing on five main emerging issues. Seoul Master Plan shows up directions of supplementary plans in terms of use, development and preservation of land. The master plan is a comprehensive plan ranging over various disciplines including society, economy, environment, energy, transportation, infrastructure, culture and welfare. The city sets up regional plans and guidelines to fill a gap between the master plan and subordinate plans. Among five main issues of the master plan, the theme of Safe City with Life Alive involves three objectives of creating an eco-city led by parks, realizing a resource circulation city with energy efficiency, and making a safe city protecting all together. Each objective is implemented in strategies, and material-related strategies are included as shown on Table 9. Specific measures, targets and detailed items are not covered in this master plan.

Table 9. Material-related Objectives and Strategies to achieve the theme of 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, monitoring system of climate change
	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

Landscape Design Guideline Manual (2012) sets up targets and strategies according to characteristics of landscape types in four categories. Generally sustainable requirements for landscape design are insufficiently described, except for greening. Material-related strategies in this manual are related to historical and cultural atmosphere and harmonization with historical resources and their unique features. Architectural materials shall be considered for its quality to suit historical surroundings and its durability. Landscape Design Guideline and Checklist specifies material qualities for each landscape zones as shown at Table 10.

Table 10. Material Qualities specified in 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 standing out and disturbing 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 standing out and disturbing the harmony such as luminous, transparent, 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 standing out and disturbing the harmony such as luminous, transparent, reflective materials Use of homogeneous roof materials with qualities and colors in harmony with Seoul City Wall at buildings visible from the wall

Urban Development Sustainable Building Environment Assessment Guideline (2011) applies to projects over the scale at environment impact evaluation target, as an urban development project. Criteria for evaluation are organized in 7 sectors with 41 items, covering land use, transportation, energy, ecological environment, resource cycling, water cycling and indoor environment. Material items include thermal insulation, environment-friendly architectural materials, recycled wastes, permeable pavement and materials with low-emission of VOC and asbestos, as shown at Table 11. These are limited to building materials. Material is recognized as a part of surfaces and buildings in specific measures to achieve goals of energy, water, and indoor environment. The concept of material as economic and social resources are not fully accepted in these guidelines, although the landscape guideline highly focuses on these values.

Table 11. Material Criteria in 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

3.5. Research Summary

From the examination of urban master plans and design guidelines, we can point out the general differences between Seoul and other three cities. London, New York and Tokyo have their urban master plans and design guidelines in close associations to set up criteria sectors, to describe requirements and to specify measures, evenly in infrastructure, landscape and building materials. But in case of Korea, there is no green certification system for urban development, which can be the basis to set up the urban design guidelines with detailed measures. All of Seoul's top Master Plan, and urban design guidelines as well as district-level master plans and guidelines show inconsistent aims and sectors for sustainability assessment.

To compare urban guidelines of each city with green certification rating systems further, this analysis uses the proposed circle of sustainable materials as a study protocol. As shown in Figure 7, each guideline has different structures, features and considerations of material requirements.

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

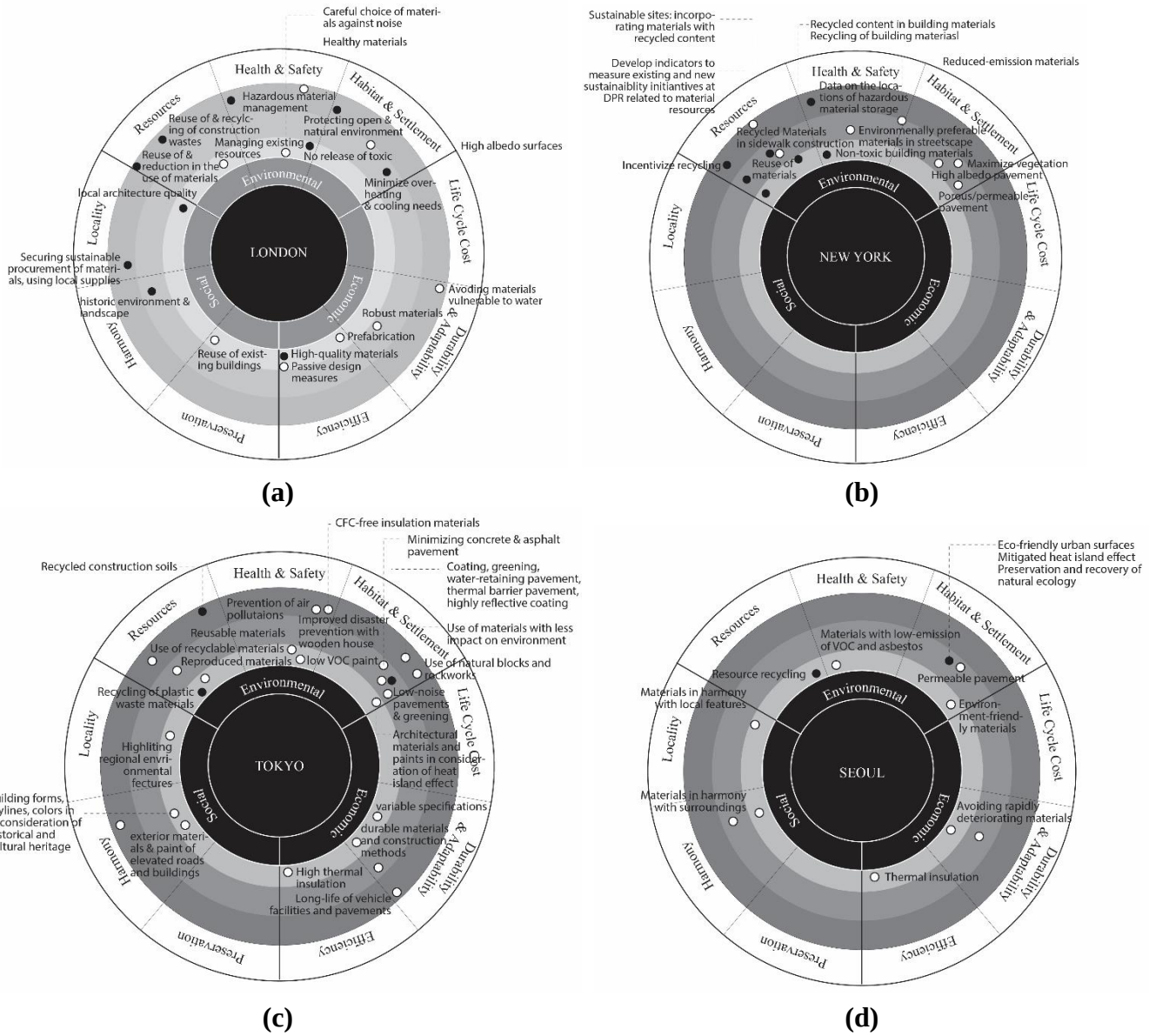
London Plan covers many sustainability issues of materials but there is no clear distinction of material uses among infrastructure, landscape and building. Urban design guidelines of London involve more sustainability issues than BREEAM Communities, in Habitat & Settlement, Locality and Harmony.PlaNYC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

guidelines is heavily weighted towards environmental issues. The material techniques and specifications are described in most details among urban design guidelines.

Although the City Planning Vision centers on only these issues, other design guidelines cover most issues in detail except for Preservation and Life Cycle Cost. Urban design guidelines of Tokyo specifies material requirements as per regions and project types, as well as materials at different scales of urban design. While CASBEE UD includes Preservation issues, Tokyo urban guidelines don't have any items as a preservation strategy.

Seoul has the least items for sustainable materials in its urban guidelines. Also, compared to other guidelines, the urban design doesn't involve the material selection and uses in infrastructure. Although the top master plan targets resource recycling, supplementary guidelines don't include any strategies and measures to develop and implement resource recycling. Many issues are approached from building materials and are not specified in details.

Figure 7. Urban Design Guidelines in Circle of Sustainable Materials
(a) London. **(b)** New York. **(c)** Tokyo. **(d)** Seoul
(●: Top-level master plan; ○: Supplementary design guideline)



In summary, London and New York have detailed material criteria in their top master plans while Tokyo has supplementary urban design guidelines specifying most sustainability issues in materials. Most of items in material criteria interact with green certification rating systems. Similarly to green certification rating systems, Life Cycle Cost isn't integrated in material criteria in none of urban design guidelines.

4. Conclusions

In this paper, the circle of sustainable materials is proposed as a tool for comparative analysis of green certification rating systems, and urban design guidelines of London, New York, Tokyo and Seoul. In the tool, evaluation criteria includes three major sectors of environment, economy and society to embrace the concept of sustainability. In addition, materials are categorized into building materials, landscape materials and infrastructure materials to cover all of material elements available in urban developments. Overview of material criteria in green certification rating systems and urban planning guidelines is discussed to summarize current system features and their weakness as balanced material assessments for the sustainable urban development as following:

First, all of green certification rating systems including BREEAM Communities, LEED ND and CASBEE UD evaluates Resources, Preservation and Durability & Adaptability for sustainable materials in common. Although there are difference of levels and strategies in assessing other sustainability issues of material, all of them pursue balanced concept of sustainable materials in environment, economy and society.

Second, all of urban design guidelines for London, New York and Tokyo share the directions and strategies for sustainable materials with green certification rating systems, but with more specific and more various measures. In case of Seoul, without a certification rating system, urban guidelines are not as fully developed as others.

Third, the structures of design guidelines, detailed material requirements and approach in different scales varies depending on cities.

Lastly, the concept of Life Cycle Cost seems hard to be incorporated in any green certification rating systems and urban design guidelines. Although preservation is the commonly shared item in certification rating systems, it is not required in urban design guidelines of all the discussed cities.

The notion of preservation and life cycle cost in material assessments and requirements should be further studied to achieve sustainability in material implementations of urban development.

Acknowledgments

This study was supported by the International Cooperation of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Knowledge Economy (No. 20123030020090).

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. James, P.; Magee, L.; Scerri, A.; Steger, M. B. *Urban Sustainability in Theory and Practice: Circles of Sustainability*; Routledge: London, UK, 2015.
2. Trade Press. Pharos Project. http://www.solaripedia.com/713/136/material.html (accessed Apr 29, 2015).
3. Solaripedia. Pharos Project Readies New Environmental Assessment Tool. http://www.facilitiesnet.com/green/article/Pharos-Project-Readies-New-Environmental-Assesment-Tool-Facilities-Management-Green-Feature--9647 (accessed Apr 29, 2015).
4. National Institute of Building Sciences. Building Materials and Furnishings Sustainability Assessment Standards. http://www.wbdg.org/resources/sustainabilityassessments.php (accessed Apr 29, 2015).
5. Rodriguez, S. I.; Roman, M. S.; Sturhahn, S. C.; Terry, E. H. Sustainability Assessment and Reporting for the University of Michigan's Ann Arbor Campus. http://css.snre.umich.edu/css_doc/CSS02-04.pdf (accessed Apr 29, 2015).
6. Buchanan, P. *Ten Shades of Green: Architecture and the Natural World*; Architectural League of NY: New York, USA, 2006.
7. BRE. *BREEAM Communities Technical Manual SD202 - 1.0:2012*; Hertfordshire, UK, 2014.
8. Congress for the New Urbanism Natural Resources Defense Council; Council, U. G. B. *LEED 2009 for Neighborhood Development*; US Green Building Council: Washington DC, USA, 2009.
9. Institute for Building Environment and Energy Conservation *CASBEE for Urban Development Technical Manual (2014 Edition)*; JSBC, Ed.; IBEC: Tokyo, Japan, 2015.
10. Greater London Authority (GLA). The London Plan official website. http://www.london.gov.uk/priorities/planning/london-plan (accessed Apr 22, 2015).
11. Greater London Authority (GLA). The London Plan: The Spatial Development Strategy for London Consolidatee with Alaterations since 2011(2015). http://www.london.gov.uk/priorities/planning/london-plan/further-alterations-to-the-london-plan (accessed Apr 22, 2015).
12. Greater London Authority (GLA). Sustainable Design and Construction Supplementary Planning Guidance(SPG)(2014). http://www.london.gov.uk/priorities/planning/consultations/draft-sustainable-design-and-construction (accessed Apr 22, 2015).
13. The City of New York. plaNYC official website. http://www.nyc.gov/html/planyc/html/home/home (accessed Apr 22, 2015).
14. The City of New York. PlaNYC : Progress Report 2014. http://www.nyc.gov/html/planyc2030/downloads/pdf/140422_PlaNYCP-Report_FINAL_Web.pdf (accessed Apr 22, 2015).
15. The City of New York. plaNYC 2011. http://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc_2011_planyc_full_report.pdf (accessed Apr 22, 2015).
16. The City of New York. High Performance Infrastructure Guidelines (2005). http://www.nyc.gov/html/ddc/downloads/pdf/hpig.pdf (accessed Apr 22, 2015).
17. The City of New York. Sustainable Urban Site Design Manual (2008). http://www.nyc.gov/html/ddc/downloads/pdf/ddc_sd-sitedesignmanual.pdf (accessed Apr 22, 2015).
18. Yang, J.-S.; Kim, I.-H.; Hwang, H.; Kwon, M.-R. *A Comparative Study on the Operational Systems of Master Plans in World Cities -London, Berlin, New York, Tokyo-*; Seoul, Korea, 2010.

19. Bureau of Urban Development - Tokyo Metropolitan Government. Planning Tokyo's Urban Development. http://www.toshiseibi.metro.tokyo.jp/eng/pdf/2014-1.pdf (accessed Apr 5, 2015).
20. Bureau of Urban Development - Tokyo Metropolitan Government. The City Planning Vision for Tokyo. http://bdi.re.kr/program/researchreport/download.asp?idx=317&file=391_061106.pdf (accessed Apr 5, 2015).
21. Tokyo Metropolitan Government. Tokyo Metropolitan Environmental Master Plan. https://www.kankyo.metro.tokyo.jp/en/attachement/Master-Plan(Outline).pdf (accessed Apr 5, 2015).