Analyzing the Shearing-Layer Concept Applied to Urban Green System

S. Pushkar, O. Verbitsky

***Abstract*—**Currently, green rating systems are mainly utilized for correctly sizing mechanical and electrical systems, which have short lifetime expectancies. In these systems, passive solar and bio-climatic architecture, which have long lifetime expectancies, are neglected. Urban rating systems consider buildings and services in addition to neighborhoods and public transportation as integral parts of the built environment. The main goal of this study was to develop a more consistent point allocation system for urban building standards by using six different lifetime shearing layers: Site, Structure, Skin, Services, Space, and Stuff, each reflecting distinct environmental damages. This shearing-layer concept was applied to internationally well-known rating systems: Leadership in Energy and Environmental Design (LEED) for Neighborhood Development, BRE Environmental Assessment Method (BREEAM) for Communities and Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) for Urban Development. The results showed that LEED for Neighborhood Development and BREEAM for Communities focused on long-lifetime-expectancy building designs, whereas CASBEE for Urban Development gave equal importance to the Building and Service Layers. Moreover, although this rating system was applied using a building-scale assessment, "Urban Area + Buildings" focuses on a short-lifetime-expectancy system design, neglecting to improve the architectural design by considering bio-climatic and passive solar aspects.

***Keywords*—**Green rating system, passive solar architecture, shearing-layer concept, urban community.

I. Introduction

SINCE 1980, a substantial amount of interest has been devoted to decreasing building-related environmental effects and promoting sustainable building-related activities. Green buildings have gained momentum and have become a trendy fashion in mainstream architectural practice. Green rating systems have been developed since the 1990s to evaluate building sustainability. Currently, the rating systems cover all building types: new constructions, domestic refurbishment, urban communities, buildings in-use, retail, schools, neighborhoods, healthcare, etc. Recently, developers of green rating systems have begun to recognize the need to develop systems for urban design evaluation. As a result, Leadership in Energy and Environmental Design v4 for Neighborhood Development (LEED-ND) [1], BRE Environmental Assessment Method (BREEAM) for Communities [2], and Comprehensive Assessment System for Building Environmental Efficiency for an Urban Area + Buildings (CASBEE-UD) [3], [4] were developed.

S. G. Pushkar is with the Department of Civil Engineering, Faculty of Engineering, Ariel University, Ariel, P.O.B. 3 Israel (corresponding author phone: 039-066-410; fax: 039-066-351; e-mail: svetlanap@ ariel.ac.il).

O. N. Verbitsky is with the Department of Civil Engineering, Faculty of Engineering, Ariel University, Ariel, P.O.B. 3 Israel (e-mail: olegv@ariel. ac.il).

The five main categories of LEED-ND v4 [1] are Smart Location & Linkage, Neighborhood Pattern & Design, Green Infrastructure & Buildings, Innovation & Design Process, and Regional Priority Credits. Each of the credits corresponds to a different number of points – some credits give ten points, while others give only one point. LEED-ND [1] allows for four certification ratings: "Certified" (40-49 points earned), "Silver" (50-59 points earned), "Gold" (60-79 points earned), and "Platinum" (80+ points earned). BREEAM for Communities [2] considers eight main categories: Climate and Energy, Resources, Place Shaping, Transport and Movement, Community, Ecology and Biodiversity, Business and Economy, and Buildings. The credits are evaluated equally and range from one to three points. Green buildings are then labeled according to six rating benchmarks: "Unclassified" (< 25% score), "Pass (>25% score)", "Good" (>40% score), "V Good" (>55% score), "Excellent" (>70% score), and "Outstanding" (> 85% score).

CASBEE-UD considers two main categories: Environmental Quality and Load Reduction. Environmental Quality (Q_{UD}) contains three sub-categories: $Q_{UD}1$ - Natural Environment (microclimates and ecosystems), $Q_{UD}2$ - Service Functions for the Designated Area, and $Q_{UD}3$ - Contribution to the Local Community (history, culture, scenery and revitalization). Load Reduction in Urban Development (LR_{UD}) includes three sub-categories: $LR_{UD}1$ - Environmental Impact on Microclimates, Façade and Landscape, $LR_{UD}2$ - Social Infrastructure, and $LR_{UD}3$ - Management of the Local Environment. CASBEE for New Construction [4] considers two main categories: Quality and Load reduction. Quality (Q) considers three sub-categories: Q1 - Indoor Environment, Q2 - Quality of Service, and Q3 - Outdoor Environment on Site. Load Reduction (LR) includes three sub-categories: LR1 - Energy, LR2 - Resources and Materials, and LR3 - Off-Site Environment. Scoring is almost uniform for all credits (there are five levels, 1-5, where level 3 is the reference score, level 5 is equivalent to the highest technical and social levels, and level 1 is the minimum conditions required by relevant legislation). According to CASBEE, green buildings are graded as follows: "C. Poor" (BEE=less than 0.5), "B-, Fairly Poor, B=0.5-1", "B+, Good, BEE=1-1.5", "A, Very Good, BEE=1.5-3", and "S, Excellent, BEE>3."

In general, different urban rating systems have notably similar sustainability categories, such as infrastructure, location, transportation, resource and energy, ecology, economy, and well-being [5]. Each category commonly includes the credits for the site and structure and the credits for the serving systems. However, they do not separate the effect of the building design from the effect of the building's systems on environmental damage and on human health. Because the building and its systems have different lifespan scales, they have different effects on the environment and on human well-being.

Relatively recently, rating systems have begun to emerge to address this concern. Currently, there are only a few criticisms regarding the LEED-ND approach [6], [7]. Reference [6] surveyed 73 LEED-ND v3 [8] projects to analyze their checklists. The author confirmed the following mean scores of the categories: Smart Location & Linkage (17.6 out of 30 possible pts), Neighborhood Pattern & Design (24.3 out of 39 possible pts), and Green Infrastructure & Buildings (only 15.2 out of 31 possible pts). The author concluded that "… the majority of location-related criteria were among the most utilized, while many of the criteria from the green construction and technology category remained among the least utilized by surveyed projects". Reference [6] also disclosed the preferences of the developers, designers, and LEED consultants toward all relevant credits for, in particular, the Green Infrastructure & Buildings category. The credits for the building (such as the credit for Solar orientation – 31.5% of projects received this credit) were less popular than the credits for the system (for example, Energy efficiency in buildings – 72.6% of projects received this credit). The project LEED-ND v3 [8] platinum aimed "no points for designing buildings with appropriated building orientation" because LEED-ND v3 [8] awards only one point for solar orientation [6]. However, the project received two points (out of three possible points) for the Energy efficiency credit for the building design [6]. Reference [6] concluded by suggesting "… that more points should be awarded for criteria such as solar orientation… Finally, the rating scale could be changed to place much greater emphasis on the green construction…" It should be noted that the rating scale in the LEED-ND v4 [1] was not significantly changed.

The following problem related to the green rating system for buildings is widely recognized: a green certification is primarily achieved by correctly sizing mechanical and electrical systems, improving the building envelope insulation, and implementing on-site renewable energy measures, whereas effective bio-climatic and passive solar architecture strategies are neglected [9]. However, notably few green-labeled buildings are properly designed to save energy. Thus, there are many criticisms of the current green rating systems, particularly LEED, which has gained popularity and international coverage.

Reference [10] discussed the LEED certification and criticized the LEED point-based approach, which can mask the design of realistically sustainable architecture. Reference [9] showed that similar to most Green-building Rating systems, LEED was a simple "point hunting" approach, and to achieve LEED Silver, which is the most common goal, one could obtain the minimum required score without improving the energy performance of the building. Reference [9] also considered an extreme case of LEED certification failure for the promising design of the San Francisco Federal Building, which was originally designed to be LEED Platinum certified. The Federal Building was designed with bio-climatic and passive solar aspects to eliminate the requirement for heating, ventilation, and air conditioning (HVAC) systems. However, at first, the building was not granted any LEED certification because the then existing LEED rating system ignored the bio-climatic and passive solar aspects. Reference [11] claimed in his book "The Green Tragedy: LEED's Lost Decade" that LEED was an incorrect solution for sustainable design. Reference [12] criticized the LEED methodology by arguing that it was inadequate for designing a project according to passive design principles. Reference [13] claimed in a recently published paper entitled "No Evidence LEED Building Certification is saving Primary Energy" that "LEED's contribution was to marry the substance of energy efficiency with popular appeal of green design. It was a brilliant marketing strategy", and he raised the following question: "However, do LEED-certified buildings actually save primary energy...?"

"The relations between separate sub-systems within a building, and of the building itself with its surroundings, are rarely linear. The performance assessing method needs to reflect that complexity [14], [19]." Therefore, [15] suggested that "as the life expectancy of a building in Israel is approximately 50 to 100 years and that of the building systems is approximately 15 to 20 years only, the requirements for these two groups of the energy sub-categories should differ..." Because buildings and mechanical systems have largely different lifetime expectancies, [15], who was in charge of the Energy Chapter of the Israeli Green Building Standard (SI5281) revisions, proposed to divide the energy category into two subcategories [16]. The first category is "building energy performance", which only considers bioclimatic and Passive and Low-energy Architecture (PLEA) aspects, and the second category is "building service systems", which includes HVAC; other mechanical systems; solar water heating; and passive Photovoltaic (PV) systems. Therefore, passive architectural strategies can be separately applied from energy-efficient HVAC decisions for every green building. This separation procedure has been included in the recently revised SI5281 [16].

II. Introducing the Shearing-Layer Concept

Reference [17] is a leading theorist of the change rate in buildings: "A building properly conceived is several layers of longevity of built components." Reference [17] identified four building timescale layers: Shell, Services, Scenery, and Set. Shell is the structure (50 years); Services include plumbing, HVAC equipment, lifts, and cables (15 years); Scenery is partitions and dropped ceiling (5-7 years); and Set is the furniture (months or weeks).

Reference [18] expanded concept of "four S's" 17], which was originally developed for interior design in commercial buildings, into a more general concept of "six S's". According to [18], an entire building can be separated into six different timescale shearing layers: Site (eternal), Structure – the foundation and load-bearing elements (50-300 years), Skin – exterior surfaces (20-50 years), Services – communication wiring, electrical wiring, plumbing, fire sprinkler systems, HVAC, elevators and escalators (10-20 years), Space Plan – interior walls, ceilings, floors, and doors (3-10 years) and Stuff – chairs, desks, phones, pictures, kitchen appliances, lamps, and hairbrushes (days to months).

Reference [17] stated "thinking about buildings in this time-laden way is very practical. As a designer you avoid such classical mistakes as solving a five-minute problem with a fifty-year solution, or vice versa." Thus, the Building layers are "slow" layers with long lifetime expectancy, i.e., "a fifty-year solution", whereas the Service layers are "speedy" layers with short lifetime expectancy, i.e., "a five-minute problem". Therefore, slow Building layers require more attention from an architect than do speedy Service layers. Because the speedy Service layers are quickly replaced, their design is less important in the initial installation (when the green certification is achieved). In contrast, because the slow Building layers are more static and not as frequently replaced, it is important to correctly design them for the initial installation.

According to [18], the "Site dominates the Structure, which dominates the Skin, which dominates the Services, which dominates the Space Plan, which dominates the Stuff." The insight of this statement is that the Site constrains the Structure, which constrains the energy efficiency of the Skin, which is related to the efficiency of the Services. Thus, the slow Building layers regulate the speedy Service layers, increasing the importance of an environmentally correct design for the Building layers.

Reference [19] proposed the adaptation of the "shearing layers concept" of Brand's six S's to green rating systems to consider long building and short service lifetime expectancies. This study considers the layers of a building by grouping them into Building layers (i.e., Site, Structure, and Skin) and Service layers (i.e., Services, Space Plan, and Stuff). Thus, it is important to use the shearing-layer concept for green systems because this concept allows for the design of green building layers and because it also considers environmental issues and environmental responsibility.

By visualizing green buildings as separate lifetime expectancy layers, building-induced environmental damage can be analyzed. Because environmental loads define the objective criteria, the suggested separation procedure can enable the allocation of green points that are more reliable to Building layers and System layers that are related to each sustainable building task. Consequently, the following question guides this study: How carefully and realistically do urban rating systems address building and system lifetime expectancies in their current configuration?

The answer to this question is determined by analyzing the shearing-layer concept as it is applied to current internationally well-known urban green systems, i.e., LEED-ND v4 [1], BREEAM for Communities [2], and CASBEE for an Urban Area + Buildings [3], [4]. Despite the number of scientific articles that have analyzed these systems [5], [20], the application of the shearing-layer concept to these systems has yet to be investigated.

III. Urban Design as Shearing Layers According to the Lifetime Expectancy

All the credits from LEED-Nd v4 [1], BREEAM for Communities [2], and CASBEE for an Urban Area + Buildings [3], [4] were separated into six shearing layers: Site, Structure, Skin, Services, Space, and Stuff. However, the detailed separation procedure results are only shown for the Green Infrastructure & Buildings (GIB) category from the LEED system as an example.

A. LEED

Table I presents the detailed separation procedure results from the GIB category. When only the GIB category is considered, the Service layers have a higher priority (19.75%) than do the Building layers (11.25%). The point separation procedure for all the credits of the GIB category is explained as follows.

The GIB P1 Certified Green Building (0 pt) and GIB c1 Certified Green Building (5 pts) aim to achieve a LEED certification for an entire building in the project. Thus, the points for both credits were divided among all layers. The GIB P2 Minimum Building Energy Performance and GIB c2 Optimize Building Energy Performance intend to reduce the required energy consumption for the heating and cooling of the building by designing the building to be energy conscious. Energy-conscious building strategies mostly depend on the designs of the building skin (insulation of the envelope, window size, type of glazing and shading, building thermal mass and night ventilation for passive cooling) and the energy-efficient HVAC systems. Therefore, the points for the credits were divided between the Skin (GIB P2: 0 pts; GIB c2: 0.5 pts) and Service layers (GIB P2: 0 pts; GIB c2: 1.5 pts). Additional credits and their maximum available points (e.g., GIB P3 Indoor Water Use Reduction (0 pts), GIB c3 Indoor Water Use Reduction (1 pt), GIB c11 Renewable Energy Production (3 pts), GIB c12 District Heating and Cooling (2 pts), GIB c13 Infrastructure Energy Efficiency (1 p), and GIB c14 Wastewater Management (2 pts)) were redistributed to the Services layer because the expected timescale (10-20 years) of these systems and appliances were equivalent.

GIB P4 Construction Activity Pollution Prevention requires the development of the best management practices (BMPs) to regulate runoff from the project site during construction. Therefore, this credit was assigned to the Site layer. GIB c4 Outdoor Water Use Reduction intends to reduce irrigation water consumption by selecting native plants or by applying an efficient irrigation system. Therefore, the credit was divided among the Space (0.5 pts), Service (1 pt), and Stuff layers (0.5 pts). GIB c5 Building Reuse provides the requirements for reusing structural elements and skin materials. Thus, the points for this credit were divided between the Structure (0.5 pts) and the Skin (0.5 pts).

TABLE I
LEED v4 FOR NEIGHBORHOOD DEVELOPMENT SEPARATION OF MAXIMUM AVAILABLE POINTS TO THE RELEVANT SHEARING LAYERS

		Layers					
		Building Layers 11.25			Service Layers 19.75		
Symbol	Credit name	Si [b]	St [b]	Sk [b]	Se [b]	Sp [b]	Stu [b]
GIB [a]	total points: 31	5	2.5	3.75	13.25	1.25	5.25
GIB P1	certified green building	0	0	0	0	0	0
GIB P2	minimum building energy performance			0	0		
GIB P3	indoor water use reduction				0		
GIB P4	construction activity pollution prevention	0					
GIB c1	certified green building	1	1	1	1	0.5	0.5
GIB c2	optimized building energy performance			0.5	1.5		
GIB c3	indoor water use reduction				1		
GIB c4	outdoor water use reduction	0.5			1		0.5
GIB c5	building reuse		0.5	0.5			
GIB c6	historic resource preservation and adaptive reuse			1		0.5	0.5
GIB c7	minimized site disturbance	1					
GIB c8	rainwater management	2					2
GIB c9	heat island reduction	0.5		0.5			
GIB c10	solar orientation		1				
GIB c11	renewable energy production				3		
GIB c12	district heating and cooling				2		
GIB c13	infrastructure energy efficiency				1		
GIB c14	wastewater management				2		
GIB c15	recycled and reused infrastructure						1
GIB c16	solid waste management			0.25	0.25	0.25	0.25
GIB c17	light pollution reduction				0.5		0.5

[a]GIB - Green Infrastructure & Buildings; [b]Si – Site, St – Structure, Sk – Skin, Se – Services, Sp – Space Plan, Stu – Stuff.

According to GIB c6 Historic Resource Preservation and Adaptive Reuse, historic buildings should not be demolished; instead, they should be rehabilitated, preserved, or restored. This requirement implies that only minor changes can be performed during these activities. In this case, 1 pt is given to the Structure layer, and 1 pt is divided between the Space Plan (0.5 pts) and the Stuff (0.5 pts) layers. GIB c7 Minimized Site Disturbance belongs to the Site layer (1 pt) because it requires developing the project on previously developed land. GIB c8 Rainwater Management requires a reduction of the runoff on site (Site layer, 2 pts) by applying green infrastructure (Stuff, 2 pts). Because GIB c9 Heat Island Reduction is devoted to site paving and roofing materials, 1 pt is allocated to the Stuff layer.

GIB c10 Solar Orientation prescribes certain orientations of the building and certain length-to-width ratios for the walls. Thus, 1 pt was allocated to the Structure layer. GIB c15 Recycled and Reused Infrastructure provides the requirements for infrastructure items, such as roadways, unit paving, water piping, and water retention tanks. Thus, 1 pt was assigned to the Stuff layer. GIB c16 Solid Waste Management is related to waste management, which is applied to domestic waste and construction debris. Thus, 1 pt was distributed among four layers: Skin (0.25 pts), Services (0.25 pts), Space Plan (0.25 pts), and Stuff (0.25 pts). GIB c17 Light Pollution Reduction seeks to improve nighttime visibility, which is related to exterior lighting appliances. Thus, 1 pt was divided between the Service (0.5 pt) and Stuff (0.5 pt) layers.

Although the separation procedure was applied to all relevant environmental categories (Table II), the priorities of the Service layers significantly decreased to 29% of the green points, with 13% for Services, 6% for Space Plan, and 10% for Stuff. The Building layers received a much higher priority (71%), with 51% of the points for Site, 10% for Structure, and 10% for Skin.

TABLE II
LEED v4 FOR NEIGHBORHOOD DEVELOPMENT FOR BUILDING SHEARING LAYERS (PTS AND PERCENTAGES) AND RELEVANT SUSTAINABILITY CATEGORIES

	Building Layers 71			Service Layers 29		
Category	Si [a]	St [a]	Sk [a]	Se [a]	Sp [a]	Stu [a]
SSL [b]	28	26	0	0	0	1
NPD [b]	41	22	6.5	4.5	0.5	3
GIB [b]	31	5	2.5	3.75	13.25	1.25
IN [b]	6	1	1	2	1	1
RP [b]	4	2	1	1	0	0
Total (pts)	110	56	11	11.25	14.75	6.25
Total (%)	100	51	10	10	13	6

[a]Si – Site, St – Structure, Sk – Skin, Se – Services, Sp – Space plan, Stu – Stuff;
[b]SSL - Smart Location & Linkage, NPD - Neighborhood Pattern & Design, GIB - Green Infrastructure & Buildings, IN - Innovation & Design Process,
RP - Regional Priority.

B. BREEAM

Table III presents the separation procedure results for the BREEAM for Communities system [2]. Again, the Site layers have a much higher priority (65%), with 39% of the points for

Site, 11% for Structure, and 15% for Skin. The Service layers have a lower priority (35%), with 12% of the points for Services, 8% for Space Plan, and 15% for Stuff.

C. CASBEE

Table IV presents the separation procedure results for CASBEE for Urban Development [3]. The Site layers have a higher priority (54%), with 42% of the points for Site, 3% for Structure, and 9% for Skin. The Service layers have a lower priority (46%), with 21% of the points for Services, 2% for Space Plan, and 23% for Stuff.

TABLE III
BREEAM FOR COMMUNITIES FOR BUILDING SHEARING LAYERS (PTS AND PERCENTAGES) AND THE RELEVANT SUSTAINABILITY CATEGORIES

	Building Layers			Service Layers		
		65			35	
Category	Si [a]	St [a]	Sk [a]	Se [a]	Sp [a]	Stu [a]
CE [b]	33	7.5	3	7	14.5	0
RES [b]	18	8	3.5	2	0.5	2
PS [b]	45	21	5.1	12.6	2.1	2.1
TRA [b]	42	23	3.6	0.6	0.6	3.6
COM [b]	12	0	0	0	0	1.5
ECO [b]	12	12	0	0	0	0
BUS [b]	15	2.2	2.8	2.8	2.8	2.8
BLD [b]	9	1.5	1.5	1.5	1.5	1.5
IN [b]	10	2	2	2	2	2
Total (pts)	196	77.2	21.5	28.5	24	15.5
Total (%)	100	39	11	15	12	8

[a]Si – Site, St – Structure, Sk – Skin, Se – Services, Sp – Space plan, Stu – Stuff;
[b]CE – Climate and Energy, RES – Resources, PS – Place Shaping, TRA – Transport & Movement, COM – Community, ECO – Ecology and Biodiversity, BUS – Business and Economy, BLD – Buildings, IN – Innovation Credits.

TABLE IV
CASBEE FOR COMMUNITIES FOR BUILDING SHEARING LAYERS (PTS AND PERCENTAGES) AND THE RELEVANT SUSTAINABILITY CATEGORIES

	Building Layers			Service Layers		
		54			46	
Category	Si [a]	St [a]	Sk [a]	Se [a]	Sp [a]	Stu [a]
$Q_{UD}1$ [b]	55	43	4	6	2	0
$Q_{UD}2$ [b]	55	29	0	0	12	0
$Q_{UD}3$ [b]	25	10	1	3	0	1
$LR_{UD}1$ [b]	59	16	0	12	15	3
$LR_{UD}2$ [b]	58	11	0	0	24	0
$LR_{UD}3$ [b]	43	15	4	6	9	2
Total (pts)	295	124	9	27	62	6
Total (%)	100	42	3	9	21	2

[a]Si – Site, St – Structure, Sk – Skin, Se – Services, Sp – Space plan, Stu – Stuff;
[b]$Q_{UD}1$ - Natural Environment (microclimates and ecosystems), $Q_{UD}2$ - Service Functions for the Designated Area, $Q_{UD}3$ - Contribution to the Local Community (history, culture, scenery and revitalization), $LR_{UD}1$ - Load Reduction in Urban Development, $LR_{UD}2$ - Social Infrastructure, $LR_{UD}3$ - Management of the Local Environment.

Table V presents the separation procedure results for CASBEE for New Construction [4]. The Service layers have a much higher priority (62%), with 33% of the points for Services, 13% for Space Plan, and 16% for Stuff. The Building layers have a lower priority (38%), with 14% of the points for Site, 11% for Structure, and 13% for Skin.

IV. DISCUSSION

Currently, the main problem with green rating systems is related to considering both building- and system-related credits without separating them based on varying lifetime expectancies and environmental damages. This work suggests the adoption of the shearing-layer concept for three well-known urban rating systems: LEED-ND v4 [1], BREEAM for Communities [2], and CASBEE for an Urban Area + Buildings [3], [4]. The credit points are divided into six shearing layers (Site, Structure, Skin, Services, Space Plan, and Stuff) based on different lifetime expectancies and scales that determine their environmental damages, as suggested by Pushkar and Shaviv [19].

TABLE V
CASBEE FOR NEW CONSTRUCTION FOR BUILDING SHEARING LAYERS (PTS AND PERCENTAGES) AND THE RELEVANT SUSTAINABILITY CATEGORIES

	Building Layers			Service Layers		
		38			62	
Category	Si [a]	St [a]	Sk [a]	Se [a]	Sp [a]	Stu [a]
Q1 [b]	65	0	0	17	22	6
Q2 [b]	45	0	12	4	10	15
Q3 [b]	25	23	0	0	2	0
LR1 [b]	40	0	0	5	33	0
LR2 [b]	45	3	15	5	0	11
LR3 [b]	30	9	0	1	16	1
Total (pts)	250	35	27	32	83	33
Total (%)	100	14	11	13	33	13

[a]Si – Site, St – Structure, Sk – Skin, Se – Services, Sp – Space plan, Stu – Stuff;
[b]Q1 - Indoor Environment; Q2 - Quality of Service; Q3 - Outdoor Environment on Site; LR1 - Built Environment Load Reduction; LR2 - Resources & Materials; LR3 - Off-site Environment.

Notably, all the considered urban rating systems perform well in the Site layers with long lifetime expectancies (eternal). LEED-ND v4 [1] for allocates 51% of the green points to this layer, CASBEE for Urban Development [3] allocates 42%, and BREEAM for Communities allocates 39%. These results were expected because these systems were developed for urban planning.

The analysis of the total Building layer and System layers percentages (Tables II-IV) reveals that LEED-ND v4 [1], BREEAM for Communities [2], and CASBEE-UD [3] use different approaches to highlight the importance of the building shearing layers. LEED-ND v4 [1] (Table II) and BREEAM for Communities [2] (Table III) focus on the importance of Building layers with long lifetime expectancies (from 20 years to eternity); 72% and 65% of the total points are allocated to these layers. However, CASBEE-UD [3] (Table IV) assigns approximately identical priorities to the Building layers (54%) and to the Service layers (46%). Moreover, CASBEE for New Construction [4] (Table V) assigns a high priority (62% of the total points) to the Service layers with short lifetime expectancies (from daily to 20 years).

A more detailed analysis of the point allocation for a list of generic sustainability categories provides additional information on the importance of Building and Service layers for the studied categories. In LEED-ND v4 [1] (Table II), the most predictable results are related to both categories: Smart Location & Linkage and Neighborhood Pattern & Design, which are notably well represented in the Site layer: 26 out of a possible 28 pts and 22 out of a possible 41 pts. However, the category Green Infrastructure & Buildings receives 19.75 out of a possible 31 pts from the Service layers. In particular, credits such as GIB c11 Renewable Energy Production (3 pts), GIB c12 District Heating and Cooling (2 pts), GIB 13 Infrastructure Energy Efficiency (1 pt), and GIB 14 Wastewater Management (2 pts) tend to promote items with short lifetime expectancies (Services layer).

In BREEAM for Communities [2] (Table III), most categories, such as Resources, Place Shaping, and Transport & Movement, assign higher priorities to the Building layers (13.5 out of a possible 18 pts, 38.7 out of a possible 45 pts, and 27.2 out of a possible 42 pts). The next three categories (Climate and Energy, Business and Economy, and Buildings) assign approximately equal priorities to the Building layers and Service layers. Only the Community (COM) category assigns a higher priority to the Service layers, which is expected because of the issues in this category. This category includes the following: COM1 Inclusive Design, COM2 Consultation, COM3 Development User Guide, and COM4 Management and Operation.

Notably, CASBEE-UD [3] (Table IV) in the ($Q_{UD}1$) Natural Environment (microclimates and ecosystems) performs well by assigning 53 out of the possible 55 pts to the Building layers. In most categories ($Q_{UD}2$ - Service Functions for the Designated Area, $Q_{UD}3$ - Contribution to the Local Community (history, culture, scenery and revitalization), $LR_{UD}1$ - Load Reduction in Urban Development, and $LR_{UD}3$ - Management of the Local Environment), approximately equal priorities are given to both Building layers and Service layers. Consequently, $LR_{UD}2$ - Social Infrastructure receives 47 out of the possible 58 pts in the Service layers. Most of the credits from this category were relocated to the Service layers because these systems and appliances have identical expected timescales (10-20 years).

For CASBEE for New Construction [4] (Table V), the category LR2 - Resources & Materials gives equal priorities to both Building and Service layers, whereas only Q3 - Outdoor Environment on Site gives a higher priority to the Building layers (23 out of a possible 25 pts). In other categories, such as Q1 - Indoor Environment, Q2 - Quality of Service, LR1 - Built Environment Load Reduction, and LR3 - Off-site Environment, the system tends to assign more points to the Service layers and fewer points to the Building layers. Moreover, in the Service layers, CASBEE for New Construction [4] emphasizes the Service layer by assigning it the highest number of green points. For example, the Built Environment Load Reduction category allocates 33 out of the possible 40 pts to the Service layer.

Reference [9] claimed that the "Energy efficiency in buildings, according to LEED, can be achieved only by improving the mechanical, electrical and hot water systems. There is no need to improve the architectural design from bio-climatic and passive solar aspects." Reference [9] further added that "The fact that all energy saving features are put in one basket...leads to the present situation." The phrase "According to LEED" in this statement refers to LEED-NC v3 for New Construction & Major Renovations [21].

This statement [9] was confirmed by comparing the shearing-layer application to three rating systems at the building level: SI5281, LEED-NC v3, and SBTool [19]. The results showed that the current version of the LEED-NC v3 rating system is mostly out of compliance with the shearing-layer concept. The system does not consider energy, water, and H&WB as important components of the Building layers [19]. However, in contrast to LEED-NC v3, the urban rating system LEED-ND v4, which gives preference to the Building layers, corresponds to the shearing-layer concept.

V. Conclusion

The current versions of the LEED-ND v4 for Neighborhood Development and BREEAM for Communities rating systems are typically consistent with the shearing-layer concept because they promote long lifetime expectancies (Building layers). However, for CASBEE-UD for an Urban Area + Buildings, which suggests to apply CASBEE for New Construction alongside CASBEE for Urban Development, improvements remain necessary. This rating system continues to pay little attention to the Service layers (particularly CASBEE for New Construction) and fails to consider architectural designs related to the bio-climatic and passive solar aspects.

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