Evaluating Sustainable Strategies for Improving Operation And Maintenance of Building Stock

Thu Thu Nway Kyaw[1], Apichat Praditsmanont[2], Martin Schoch[3]
[1]School of Management Technology, Shinawatra University, Thailand
[2]School of Management Technology, Shinawatra University, Thailand
[3]School of Architecture and Design, King Mongkut University of Technology Thonburi, Thailand
Corresponding author: thuthunk@gmail.com

ABSTRACT

With increasing building stock worldwide, sustainable building rating (or assessment) schemes for the operation and maintenance of existing buildings are becoming a significant part for sustainable building development. Supporting stakeholders' effort in improving their existing buildings to become more sustainable, strategies of such rating schemes are expected to significantly contribute to the global demand for achieving improved sustainable building targets.

This research focuses on the comparison of two rating schemes for worldwide application, BREEAM In-Use and LEEDEB:OM, to better understand similarities, differences, and overall benefits for the sustainable development of existing commercial buildings in Thailand.

The study is divided into three parts: a quantitative analysis based on comparable criteria of performance and scheme contribution in sustainable benefits, implementation plan and cost (capital cost and maintenance cost); a qualitative analysis based on sustainable and user oriented benefits; and an analysis of non-comparative criteria of sustainable benefits, implementation plan, and cost.

Results found that in terms of quantitative analysis, BREEAM In-Use has a marginal advantage when compared to LEED EB:OM. Considering the qualitative analysis, BREEAM In-Use indicates higher benefits in 18 out of 27 comparable criteria with LEED EB:OM demonstrating higher benefits in 7 comparable criteria, and the remaining criteria having equal benefits. Considering the total rating criteria of 55% of non-comparative criteria, about 43.33% is for BREEAM In-Use and 11.67% for LEED EB:OM. With both rating schemes being close in their overall performance, one suggestion for improvement is the combination of individual categories to reach higher sustainable benefits regarding existing building stock.

KEYWORDS: *sustainable building stock, sustainable rating scheme, BREEAM In-Use, LEED EB:OM*

1. INTRODUCTION

Worldwide, buildings construction and operation contributes to 32% of the world's resources consumption; it also accounts to more than 40% of the world's total primary energy usage and another 40% of material waste disposal to landfills (Sustainable Built Environments, 2007). While it is estimated that sustainable building development could reduce 30 - 50% of the total energy usage, 35% of buildings CO_2 emission, 70% of waste outputs, and 40% of the potable water consumption (UNEP-DTIE, 2012), many rating schemes for sustainable building primarily focus on the development of buildings that are to be newly constructed only.

This seems controversial, considering that the amount of new building constructions represents less than 1% annually when comparing to building stock (Konstantinou & Knaack, 2013). Just aiming at improving new building constructions seems to have slight impact since it is estimated that nearly 60% of the world's electricity is consumed by residential and commercial building stock only (UN Environment Programme (UNEP), 2003). Especially during a building's operation and maintenance (OM) period, its resource usage, waste disposal, and maintenance policy directly affect the life cycle and performance of the building, the well-being of its occupants, and the impact on its immediate and distant environments to a large amount (World Green Building Council, 2014). Iwaro & Mwasha (2013) also concluded that sustainable strategies for the OM of existing buildings have the potential to significantly decrease the negative impact on the environment, improve indoor environmental quality, reduce resource usage, and have the financial benefit on building stake holders. Moreover, such sustainable improvements also provide safe places for occupants and users, and thus improve the occupants' health, well-being, and convenience through better work practice and lifestyles (American Physical Society (APS), 2008).

The concept of most sustainable building rating schemes is primarily based on a balance between economic, social, and environmental evaluation criteria (Rodenburg, 2010), typically applying qualitative and quantitative assessment methods due to the diverse characteristic of criteria (Biswas & Krishnamurti, 2012).While many sustainable operation and maintenance (OM) rating schemes for building exist, only a few may be applicable internationally where varying requirements due to climatic, social, or environmental need to be considered (RREEF Real

Estate, 2012). To advance building stock improvement, sustainable building rating schemes require for continuous development and progression that lead to a wider understanding and easier application.

This paper compares the two most widely adopted sustainable building rating schemes that relate to operation and maintenance (OM) strategies for existing building: BREEAM In-Use (Building Research Establishment's Environmental Assessment Method) and LEED EB:OM (Leadership in Energy and Environmental Design for Existing Building Operation and Maintenance). The objective of this study is to determine the effectiveness and usefulness of these two schemes and to propose improvements if applicable. The study aims at evaluating the similarities and differences between two schemes of sustainable rating criteria of design practices, guidelines and implementation plans, and providing the rating criteria of sustainable benefits, implementation plan and cost input level to stakeholders for developing sustainable building stock.

2. LITERATURE REVIEW

2.1 Benefit of sustainable buildings

The improvement of building stock in regard to sustainable considerations has various benefits such as profitability of the edifice, well-being for its users and occupants, or caretaking of its affected environment. Eventually, with most concepts of sustainability including such goals, they are typically structures into such categories of benefits, which are economic, social, and environmental qualities (Design Build, 2011). Economic benefit on buildings are to reduce capital and operating cost, decrease repair and maintenance cost, and lower risk, liabilities and property loss on building and its occupant (Urban Catalyst Associates, 2005). In addition, sustainable strategies improve the working productivity that is affected by building indoor environmental quality (World Green Building Council, 2014). Sustainable schemes of environmental benefits are to reduce the natural resources usage (Rodenburg, 2010), decrease air pollution and greenhouse gas emission (U.S. Department of Energy, 2003), reduce solid waste, soil, water, and noise pollutions, and protect and enhance biodiversity and eco-scheme (Dutch Green Building Council, 2013).

One factor of social benefit is to improve the building occupants' health by reducing the Sick Building Syndrome, Allergy, and Asthma Symptoms (EPA, 2008). The indoor environmental quality of HVAC scheme, indoor air quality, thermal comfort condition, and functional supply scheme also effects on a quality life of occupants' health, comfort, wellbeing, and safety (Carleton University, 2013). Moreover, social benefits are to improve occupant comfort, satisfaction, and wellbeing, develop occupant convenience, and encourage occupant safety and security (Building and Construction Authority (BCA), 2010).

2.2 Sustainable building design and integrated design process

Sustainable building design requires non-linearity in decision-making (American Society of Interior Designers (ASID), 2006). It needs to be achieved within the criteria of performance, quality, and costs with additional criteria of all sustainable benefits. Even for the renovation, or refurbishment of buildings, an integrated design (and planning) process (IDP) is required to improve the efficiency and effectiveness of the complex design process for the design professionals to implement a sustainable building design successfully (Kgokong, 2012).

Consisting of iterative occurrences of combined planning; it encourages knowledge sharing among significant team members that play a critical role during all phases and ensures successful implementation of sustainable building features throughout. The team includes owner, key users, facilities directors, programmers, real estate managers, designers and engineers (i.e. architect, landscape architect, mechanical engineer, electrical engineer), specialized consultants, service group, and facility team and/or maintenance staff (Edwards, 2011).

2.3 Implementation plan and cost input for sustainable building

When considering possible options of handling obsolete or dysfunctional building stock, its refurbishment and improvement can become a better choice than the demolishing and disposal of the building (Miller & Buys, 2011). Rating tools can help to improve the overall building performance, upgrade the operation and maintenance process and management scheme of the existing building (Building and Construction Authority (BCA), 2010). Such approach foresees a building analysis at an early stage, where designers, facility teams and operators gather information about the current building condition before an object of sustainable building improvement is defined (Ali, Noordin, & Rahmat, 2005).

The upgrade plans can be different depending on sustainable strategies, project budget, and benefits outcome. The outcome may include development in various areas, such functional building usage, building envelope, building scheme and service scheme improvement, as well as procedural changes during operation (Building and Construction Authority (BCA), 2010). Nordic Innovation (2014) defined that the action types of upgradeable performance plans are minor repair or maintenance, replace the existing equipment and control schemes with sustainability, upgrade the major plants and services schemes, or major refurbishment. The team also estimates the life-cycle costs which the building owner needs to consider when investing (Miller & Buys, 2011).

2.4 Sustainable rating scheme for existing building

There are over 400 green certification schemes having been issued worldwide, according to the Stewart (2010). A study carried out on eight certification schemes by the Brisbane City Council (2004) found that only two organizations that provide sustainable building assessment schemes, LEED and BREEAM, can cover all building types; all design stage levels (design, construction, operation, and management), and allow for international certification. According to Sarimanoglu (2010), "BREEAM and LEED are the two most representative building environmental schemes in world". Consequently, considering the sustainable development of existing buildings, BREEAM In-Use and LEED EB:OM demonstrate being the only internationally applicable, measurable, and useable rating tool as well.

2.4.1 BREEAM In-Use

Building Research Establishment's Environmental Assessment Method (BREEAM) scheme is to mitigate the life cycle impacts of buildings on the environment, to provide cost effective solutions and to quantify measurement for determining building performance (BRE, 2012).

The BREEAM In-Use scheme is a rating tool that can be used internationally and conducted for all existing commercial building types which have been operational for at least two years. It is, however, not applicable to residential dwellings. The scheme offers guidelines for the preparation of major building maintenance and daily maintenance or small-scale renovation. BREEAM In-Use reviews and measures nine categories or sectors of building scheme. As exemplified under Table 1, the assessment of each category constitutes of three separate assessment parts: asset rating, building management rating, and occupier management rating, each having different categories, sub-categories, and credit points.

Table 1. REEAM In-Use Rating System

Categories	Part 1: Asset	Part 2: Building Management	Part 3: Occupier Management	Credit Points
Management	0%	15.0%	12.0%	62
Water	8.0%	5.5%	3.5%	133
Energy	25%	31.5%	19.5%	325
Health & Wellbeing	21%	15.0%	15.0%	166
Material	12%	7.5%	4.5%	153
Waste	3.0%	0%	11.5%	112
Pollution	14.0%	13.0%	10.5%	166
Land Use & Ecology	8.0%	12.5%	5.0%	34
Transport	9.0%	0%	18.5%	128
Total	**100%**	**100%**	**100%**	**1279**

2.4.2 LEED EB:OM

Leadership in Energy and Environmental Design (LEED) was established by USGBC in 1993, aiming to construct sustainable practices in the construction industry. The LEED for existing building operation and maintenance (LEED EB:OM) rating scheme was developed in 2009 with focus on maximizing operational efficiency and minimizing environmental impacts during the building operation phase (USGBC, 2010). The rating scheme can be applied for a large variety of building types, having the following exceptional conditions: 1) The building gross floor area must have a minimum of 1,000 square feet (93 square meters), 2) The building has been operational for at least one year; and 3) The rating is targeted to single buildings, if there are multiple buildings included on the premise, each must certify individually (U.S. Green Building Council (USGBC), 2014). Exemplified in Table 2, LEED EB:OM addresses seven categories for measuring the building operation. Its assessment is based on the number of points for individual credits achieved and the culmination of its seven categories specific credits.

Table 2. LEED EB:OM Rating System

Categories	Rating Percentage	Credit Points
Water Efficiency	10.91%	12
Energy & Atmosphere	34.55%	38
IEQ	15.45%	17
Material & Resources	7.27%	8
Sustainable Sites	9.09%	10
Location & Transportation	13.64%	15
Innovation	5.45%	6
Regional Priority	3.64%	4
Total	**100%**	**110**

3. RESEARCH METHODOLOGY

This research is based on a comparative analysis between the two rating schemes, BREEAM-NL In-Use V1.0 for existing buildings (BREEAM In-Use), and LEED v4 of building operation and maintenance scheme (LEED EB:OM). Both rating schemes classify into commonly defined categories of building improvement, such as energy usage, water usage, indoor environmental quality (or health in BREEAM In-Use), material, waste, transportation, land use and ecology (or sustainable site in LEED EB:OM) and pollution. Each category groups related criteria that suggest specific measures of building improvement.

The research is realized by a process of evaluation and data collection of meaningful characteristics that help determine the benefits and usefulness of each criterion and its measures,, and a comparison of related criterion between the two rating schemes, and an analysis of their compared individual and combined performances. The research is divided into an evaluation process, followed by a comparative analysis.

3.1 Evaluation process

To better understand the two ratings schemes for improving building stock, an evaluation process is foreseen by evaluating and rating specific quantitative and qualitative characteristics of an individual criteria of the rating schemes.

3.1.1 Quantitative evaluation

A quantitative evaluation focuses on estimating the effectiveness of individual criteria to improve an existing building in terms of implementation level, cost level and sustainable benefit level. For each criterion, each level and respective sublevel are rated by integer scores between 0 and 4, with 0 representing the lowest benefit (Level 0) ,and 4 the highest benefit value (Level 4). The rating is based on the researchers experience in the field. To avoid eventual subjectivity, misinterpretation or lack of knowledge, the results were presented to a field related working group, with corrections being made according to the discussed results.

3.1.1.1) Implementation and support benefit level (IBL)

To improve the existing building, the amount of improvement and the number of support required should be considered. Under this level, scores are given to rate the anticipated amount of implementation to satisfy the task, as well as the expected amount of additional support from staff and experts to do so. The score definition for rating criteria regarding Implementation and Support is defined as follows:

- Level 4: No Implementation needed
- Level 3: Low Implementation (Adjustments and upgrade for aesthetics purposes)
- Level 2: Medium Implementation (Replacements and small improvement)
- Level 1: Intermediate (Considerable improvement required)
- Level 0: High Implementation (Major improvement required)

The score definition for Support is defined as follows:

- Level 4: can be managed and realized by building owner and/or user
- Level 3: Level 4, but further requires for facility manager and internal staff
- Level 2: Level 3, but further requires engineer or external service group
- Level 1: Level 2, but further requires specialized consultant
- Level 0: Level 1, but further requires for an expertise

3.1.1.2) Cost benefit level (CBL)

The probable amount of initial investment costs, as well as operation and maintenance costs, are considered for each rating criteria. The score definitions for anticipated capital cost are:

- Level 4: No significant capital cost required
- Level 3: Low investment cost (under maintenance budget)
- Level 2: Moderate investment Cost (low budget - less than 5-year payback)
- Level 1: Intermediate Cost (medium budget cost - less than 10-years payback)
- Level 0: High Cost (high budget cost – more than 10-years payback)

The score definitions for anticipated operation and maintenance, including operating cost, maintenance and repair cost, regular check cost, and professional check cost are:

- Level 4: No cost
- Level 3: Low Cost: (one cost types involved)
- Level 2: Moderate Cost: (two cost types involved)
- Level 1: Intermediate Cost (three cost types involved)
- Level 0: High Cost (L2 or L1 + external service required)

3.1.1.3) Sustainable benefit level (SBL)

The sustainable benefits level considers the economic, ecological, and social benefits of the implemented measures. Economic benefits positively rate the reduction of operating and disposal cost, maintenance and repair cost, risk and property loss, as well as the increase of work productivity. Ecological benefits acknowledge the decrease use of natural resources, the reduction of air pollution and greenhouse gas emissions, waste and pollution, as well as the protection and enhancement of biodiversity. Social benefits improve occupant's health, comfort, satisfaction and wellbeing, develop occupant convenience, and safety and security. The overall scores for Sustainable Benefits are:

- Level 4: No Benefit
- Level 3: Low Benefit: (one benefit type achievable)
- Level 2: Moderate Benefit: (two benefit types achievable)
- Level 1: Intermediate Benefit (three benefit types achievable)
- Level 0: High Benefit (four or more benefit types achievable)

3.1.1.4) Equations for evaluation

With the rating score consistently applied for all assessment levels, a further definition for the average value of each benefit level is necessary. For each sector, the cumulated results of the evaluation level are displayed separately, and in total percentage (1-100%), as expressed in Eqs.1-4:

Implementation Level (IBL) = (Implementation Plan + Support Need)/8 x 100%

(1)

Cost Benefit Level (CBL) = (Capital Cost + OM Cost)/8 x 100%

(2)

Sustainable Benefit Level (SBL) = (Economic Benefit +Environmental Benefit +Social Benefit)/12 x 100%

(3)

Overall Benefit Level (OBL)= (IBL + CBL + SBL)/3
(4)

3.1.2 Qualitative comparison

A qualitative comparison is based on the understanding that a criterion might be easier applicable when knowing of possible advantages such as complexity of the measure and the method used, the anticipated effort to satisfy the measure, or the provision of descriptions, guidelines, tools, or other means of support. A qualitative appraisal often becomes meaningful, when quantitative evaluations suggest a draw. Instead of score evaluation, which typically defines quantifiable values, three types of 'star' rating determine a criterions qualitative value, instead. The star rating is defined as follows:

- White star (☆): With different measures, a considerable advantage of the criterion to its respective probe is determined.
- Black star (✪): With similar measures, a considerable advantage of the criterion to its respective probe is determined.
- No star: No considerable advantage of the criterion to its respective probe is determined.

Note: ✪=High Benefit, ☆=Benefit but Different Approach.

Like the quantitative assessment, corrections of the evaluation were made based on a working group presentation response.

3.2 Comparative analysis

To allow for relative evaluation, a comparative analysis of the two rating schemes is carried out. Due to the distinct character of individual rating criteria, the comparative analysis is divided into groups of comparable and non-comparable criteria.

3.2.1 Comparable criteria

Comparable criteria define a group, where an individual criterion of a rating scheme is identical, or at least alike a criterion of the second scheme. Thus, such can be compared quantitatively, as well as qualitatively. For example, IEQ or Health sector of "Thermal Comfort Conditions" criterion is included in both schemes, referred to as "Thermal Comfort in Climatic Conditions" criteria in BREEAM in-Use, it is stated as "Thermal Comfort" in LEED EB:OM.

3.2.2 Non-comparable criteria

Non-comparable criteria are the group of criteria, where an akin criterion does not exist in the second scheme. For example, Material sector of "Security Alarm Scheme" criterion is mentioned in BREEAM In-Use rating scheme and is not measured in the LEED EB:OM scheme. Yet, while a non-comparable criterion may not be directly comparable with others, a quantitative evaluation is still possible to determine its effectiveness regarding building improvement. Thus, the qualitative assessment can ascertain information regarding its beneficial strength and usefulness. For example, IEQ or health sector of Thermal Comfort criterion is mentioned in both schemes and criterion is intended to promote occupants' productivity, comfort, and well-being by providing quality thermal comfort. But LEED EB:OM rating scheme provide more information for the monitoring scheme of rating criterion performance.

Considering the qualitative evaluation of comparable and non-comparable criteria, the analysis focuses on identifying the performance of each single criterion, as well as combined within a category. In doing so, the overall performance of categories can be understood, and eventual variations of individual members are identified.

4. COMPARATIVE ANALYSIS AND RESULTS

4.1 Comparable criteria – quantitative evaluation

When considering quantitative results of comparable criteria, results show that the two rating schemes indicate only marginal differences. This seems understandable since comparable criteria are likely to have a similar approach in terms of implementation measures and documentation. Yet, differences between comparable criteria could be found and documented. An overview of the quantitative evaluation is shown, and better results are highlighted in Table 3.

Table 3. Overview Quantitative Evaluation - Comparable Criteria

Criteria Categories	**BREEAM In-Use**			
	IBL%	**CBL%**	**SBL%**	**OBL%**
Water Saving	62.50%	62.50%	**33.33%**	**52.78%**
Energy Conversation	**42.50%**	**47.50%**	33.33%	41.11%
Health & Wellbeing or IEQ	48.25%	53.60%	**40.42%**	**47.39%**
Material	58.36%	66.75%	**69.50%**	**64.88%**
Waste	56.25%	62.50%	**37.50%**	**52.08%**
Pollution	43.25%	37.50%	37.50%	39.58%
Sustainable Site or Land Use	43.25%	43.25%	29.17%	38.89%
Transportation	66.75%	58.25%	41.67%	55.56%

Criteria Categories	**LEED EB:OM**			
	IBL%	**CBL%**	**SBL%**	**OBL%**
Water Saving	62.50%	62.50%	30.50%	51.85%
Energy Conversation	40.00%	45.00%	**41.67%**	**42.22%**
Health & Wellbeing or IEQ	48.25%	53.60%	38.08%	46.61%
Material	**66.63%**	**70.88%**	55.50%	64.33%
Waste	56.25%	62.50%	29.17%	49.31%
Pollution	43.25%	37.50%	37.50%	39.58%
Sustainable Site or Land Use	43.25%	43.25%	29.17%	38.89%

Transportation	66.75%	58.25%	41.67%	55.56%

The evaluation results of comparable criteria by category are summarized as follows:

- Water saving shows almost identical results, with BREEAM In-Use marginally better when considering Sustainable Benefit Level (SBL).
- Energy conservation shows similar overall results however with varied performance where BREEAM In-Use shows better Implementation Benefit Level (IBL) and Cost Benefit Level (CBL) rating while LEED EB:OM have better SBL outcomes.
- In Health or IAQ, BREEAM marginally better in terms of SBL
- In Material, BREEAM shows better SBL while LEED EB:OM has better IBL and CBL
- In Waste, BREEAM indicates improved SBL.
- For the categories of pollution, sustainable site or land use, and ecology, as well as transportation, the differences could not be found.

Overall evaluation results of quantitative comparable criteria of two rating schemes suggests that BREEAM In-Use seems to have slightly better sustainable benefits, at least under the categories of Water Saving, Energy Conservation, Health, Material, and Waste. Benefit level evaluation results for each category of rating criteria are:

- Categories that could reach high IBL (above 60%), implicates that these might be easily implemented, and / or require small amount of experts or professionals support. They were Water Saving and Transportation. Criteria that reached high IBL values (3 or more) were water metering scheme, water use reduction, energy metering scheme, facilities for separate waste, purchasing material, supply chain, site development plan, transportation survey, and transport reduction target.
- Categories that could reach high CBL (above 60%), indicates that criteria of such categories might require little capital cost and / or have little financial impact when considering operational cost. They were Water Saving, Material and Waste. Criteria with high CBL ratings (3 or more) were water metering scheme, water use reduction, energy metering scheme, optimize energy performance, day lighting and view, occupant comfort and satisfaction survey, supply chain, facilities for separate waste, site development plan, and transportation survey.
- The only category that could reach high SBL (above 60%) was Material, suggesting a large amount of sustainable benefits can be achieved. Criteria with high SBL ratings (3 or more) were material supply chain, and building management and maintenance policy.
- Finally, the categories that could reach good Overall Benefit results (above 50%), are Water Saving, Material, Waste and Transportation.

4.2 Comparable criteria - qualitative evaluation

In terms of qualitative results of comparable criteria, results show that the two rating schemes indicate differences, as illustrated in Table 4.

Table 4. Comparable Criteria of Qualitative Analysis

Category	Comparable Criteria	BREEAM In-Use	LEED EB:OM
Water	Water Metering Scheme	✪	-
	Water Efficient Fixture	✪	-
	Water Use Reduction	✪	-
Energy	Energy Metering Scheme	✪	-
	Optimize Energy Performance	☆	☆
	Energy Conservation Program	-	✪
	Renewable Energy	☆	☆
	Building Commissioning	-	✪
Health and Wellbeing (IEQ)	IAQ Performance	✪	-
	Enhanced IAQ Strategies	✪	-
	Thermal Comfort	-	✪
	Day Lighting and View	✪	-
	Artificial Lighting	-	✪
	Occupant Comfort Survey	✪	-
	Cleaning Policy & User Safety	✪	-
Material	Purchasing Sustainable Material	✪	-
	Supply Chain	✪	-
	Building Management and Maintenance	✪	-
Waste	Facilities for Separate Waste Stream	✪	-
	Waste Management	✪	-
Pollution	Refrigerant Management	-	✪
	Light Pollution	-	✪
Sustainable Site	Site Development Plan	✪	-
	Site Improvement Plan	-	✪
Transportation	Transportation Survey	✪	-
	Transport Reducing Target	✪	-
	Transport Management Policy	✪	-

Accordingly the following observations can be made:

- Overall BREEAM 18/2 vs LEED 7/2, means that in a one to one comparison of similar, of equally performing criteria of the two rating schemes, BREEAM In-Use criteria are likely to have better qualitative evaluation.
- Considering the categories by categories, water, health and wellbeing, material, waste, and transportation categories in BREEAM have better benefit while LEED has better qualitative benefit in energy and pollution categories.

Looking at the relationship of comparable criteria of quantitative and qualitative results, BREEAM might be a more holistic rating scheme, where positive evaluation appears in a widely distributed manner.

4.3 Non-comparable criteria – qualitative evaluation

Non-comparable criteria contribute about 43.33% to the overall BREEAM assessment, and 11.67% to LEED ratings respectively. To succeed in achieving higher ratings, a closer look at the evaluation of non-comparable criteria is required. Since no comparison is involved, the resulting qualitative evaluation documents how individual non-comparable criteria might be suitable when considering individual benefits. Figure 1 shows how individual non-comparable criteria perform in terms of implementation level, cost benefit level, sustainable benefit level, but also combined as an overall benefit level.

Overlooking the evaluation results, observations can be made as follows:

- Overall performance high ranking (60% or higher) criteria were identified as:
  - BREEAM: guideline for water usage, energy saving tips (63.9%), reduction and prevention of pollution (63.9%), shared parking (65.3%), and proximity with transport and basic facilities (70.8%).
  - LEED: site management policy (65.3%)

- Overall performance low ranking criteria (40% or lower) were identified as:
  - BREEAM: separate sewer and rainwater (37.5%), recycle water and rainwater usage (25.0%),, control flood risk (38.9%), control discharge waste water (33.3%), and biodiversity management plan (27.8%),
  - LEED: cooling tower water use (33.3%), IAQ management program (33.3%), and rainwater management (37.5%)

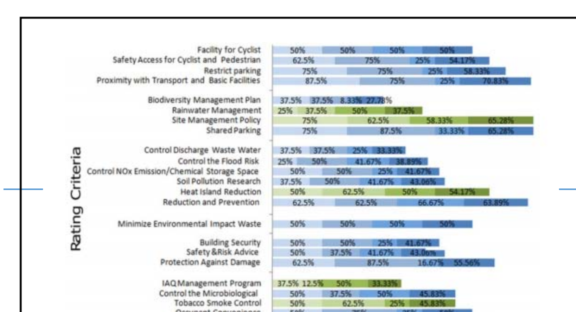

Fig 1. Non-Comparable Criteria of Quantitative Analysis

- Considering the implementation benefit level, the well performing criteria (60% or higher) were identified as:
  - BREEAM: guideline for water usage (62.5%), maintenance program for water scheme (62.5%), energy saving tips (62.5%), energy consumption target (75.0%), protection against damage (62.5%), reduction and prevention of pollution (62.5%), shared parking (75.0%), proximity with transport and basic facilities (87.5%), restrict parking (75.0%), and safety access for cyclist and pedestrian (62.5%).
  - LEED: Integrated pest management policy(62.5%),, and site management policy(75.0%),

- Considering capital cost benefit, the well performing criteria (60% or higher) were:
  - BREEAM: guideline for water usage (87.5%), install leak detection (87.5%), maintenance program for water scheme (62.5%), energy saving tips (62.5%), energy consumption target (75.0%), measure air leakage (75.0%), occupant convenience (75.0%), protection against damage (87.5%), reduction and prevention of pollution (62.5%), shared parking (87.5%), proximity with transport and basic facilities (75.0%), restrict parking (75.0%), and safety access for cyclist and pedestrian (75.0%).
  - LEED: Integrated pest management policy (62.5%), tobacco smoke control (62.5%), heat island reduction (62.5%), and site management policy (62.5%).

- Considering sustainable benefits, the well performing criteria (60% or higher) were
  - BREEAM: reduction and prevention of pollution (66.7%),

4.4 Results

With rating schemes consisting of comparable and non-comparable criteria, a result of identifying a superior rating scheme in terms of implementation effectiveness, cost and sustainable benefits is inconclusive. Instead, with the research focusing on different evaluation methods for comparable and non-comparable rating criteria, the following results were attained.

- Considering quantitative results of comparable criteria, BREEAM In-Use and LEED EB:OM are almost similar when considering evaluation results, yet a marginal advantage of BREEAM In-Use is of perceived as shown in Table 3
- Considering qualitative evaluation results of comparable criteria, BREEAM In-Use indicates to have better feedback than LEED EB:OM, as not only more star ratings were given, but the ratings are more distributed over the criteria categories, too
- In terms of non-comparable criteria, the results are diverse with individual criterion showing individual strength in the evaluated areas, suggesting that their advantage is to be seen in their flexibility to be applied when deemed suitable. Yet, it should be recognized that BREEAM In-Use has by far more non-comparative criteria than LEED EB:OM (by number 27 to 7), this suggests that the increased amount of measures could implicate negative effects in terms of implementation or cost benefits.
- Another significant observation is that most non-comparable criteria rather display moderate sustainable benefit achievement, with only one BREEAM criterion (Reduction and pollution prevention) achieving high Sustainable Benefit Level (SBL) result.

The research revealed that the comparison led to rather balanced results, where one rating scheme does not drastically distinguish itself from to the other. While it can be said that BREEAM In-USE indicates a slight advantage towards LEED EB:OM, mostly in terms of comparable criteria, the BREEAM In-USE also requests for more sustainable criteria to be fulfilled. Such may be positive in terms of sustainable benefits, but may also create disadvantage relating to implementation, need of professional support and increased capital costs.

5. CONCLUSIONS

Achieving sustainable building stock by refurbishing existing buildings requires for well understood guidance and support from sustainable building rating schemes. By exploring two internationally recognized sustainable building rating schemes for improving building stock, understanding regarding similarities and differences of their assessment could be provided in terms of implementation benefit, cost benefit and sustainable benefit levels. Results indicate that the rating of the schemes do not distinguish themselves considerably when overlooking the overall comparison result. Thus, it can be said that the selection of a rating scheme may better follow stakeholders' individual preferences of specific assessment categories and their performance strength as part the respective scheme. In terms of overall benefits, a more distinguished rating scheme may be achieved by combining well performing criteria of individual rating schemes. Such exploration is suggested as future research.

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