The Differences of Typical Assessment Standard Systems for Green Building and Implications for China

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Abstract. In the energy crisis and the deterioration of the ecological environment, the harmonious development of architecture and the environment is the solution. All the countries in the world have issued corresponding plans for the development of green building. The green building evaluation standard systems are the main components of the programs. The evaluation systems of the United Kingdom, the United States, Japan, and China are compared. This article discusses the similarities and differences in terms of green building concept, evaluation objects, and indicator system. Although the focuses of evaluation systems are slightly different, the core concept of green building is basically the same, that is to establish the built environment at the minimum environmental cost. The evaluation objects are mainly residential building and public building. The indicator systems reflect the key points concerned by the countries. The implications including keeping the dynamic development of the evaluation system, increasing the flexibility of the evaluation system based on accuracy, and paying attention to the influence of human factors on green buildings are proposed.

1. Introduction
With the development of society, the exhaustion of energy resources and environmental pollution have become serious problems that have threatened the future of mankind. The construction industry consumes a lot of energy and resources. The balance between creating comfortable living environment and environmental impact is the only solution. Green building is a concrete manifestation of this concept. Various countries have formulated green building development programs. They are mainly Building Research Establishment Environmental Assessment Method (BREEAM) of U.K., Leadership in Energy and Environmental Design (LEED) of US., Comprehensive Assessment System for Building Environmental Efficiency of Japan and found by Natural Resources Canada and developed by international initiative for a Sustainable Built Environment (iSBE), Sustainable Building Tool, etc. In 2006, China's Ministry of Construction formulated Assessment Standard for Green Building GB/T50378-2006 (GBL), which is the first one in Green building evaluation system in China. China's green building evaluation standard has developed rapidly in the past 10 years. However, there are some problems. The standard gave too much value to the technology itself, ignoring the effect of the technology during the operation. In the granted start-rating projects, only 7% of them are green buildings in operation [1]. Some project invested much money on expensive equipment to get points in the green building assessment. Lacking of management skill, the equipment was idled. This phenomenon seriously violates the original intention of implementing the green building evaluation
standard. How to correct problems in the evaluation of green buildings in China by adjusting standard content is worth studying. Green building evaluation systems in the United Kingdom and the United States have been developed for many years. The differences obtained by comparing the standards can indicate the direction of improvement of China's green building evaluation standards.

2. Green building concept
The definition of green buildings which is the basis of assessment standard for green building, is not exactly the same in each country (table 1). The U.S. Green Building Council believes that green buildings should have a positive impact and less negative impact in life cycle [3]. British Building Ecology Center states that the creation and responsible management of a healthy built environment based on resource efficient and ecological principles [3]. The definition of China's green building assessment standard is that during the life cycle of a green building, resources are saved (energy saving, land saving, water saving and material saving), to protect the environment, reduce the pollution, provide people with a healthy, applicable and efficiency space, in harmony with nature [4]. Japan Sustainable Building Association evaluates green building by Building Environmental Efficiency (BEE), which is environment quality divided by environmental load in Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) [5]. Overall, green building concept includes two aspects of building construction and environmental impact. The emphasis on these aspects is different. It determines the indicators for environmental impact and weight coefficients in the rating system of each assessment standard.

Table 1. Green building concept of different countries

| Country | Green building concept |
|---------|-----------------------|
| US.     | The green building is comprehensive composition with more positive impact and less negative impact on the environment in Life Cycle. |
| U.K.    | The creation and responsible management of a healthy built environment based on resource efficient and ecological principles. |
| China   | During the life cycle of a green building, consuming the least resources, including energy, land, water and material, having saved environment and reduced pollution, a healthy, applicable and efficiency space is provided in harmony with nature |
| Japan   | The smallest environmental load, the best quality of the environment |

3. Green building rating system

3.1. Development process

3.1.1 Development process of BREEAM. Building Research Establishment Environmental Assessment Method (BREEAM) was founded in 1990, which is the first and most widely used green building assessment method in the world. LEED of was established in 1998, developed on the basis of BREEAM. Because the evaluation system adopts the core concept of according to local conditions and balancing benefits, making BREEAM the only green building evaluation system with both globalization and localization characteristics. It is both a set of evaluation criteria for green buildings and a best practice method for the design of green buildings. It should also be the most authoritative international standard for describing the performance of the built environment.

3.1.2. Development process of LEED. In 1994, the United States Green Building Committee drafted a green building rating system. In 1998, Energy and Environment Design Version 1.0 was issued. The latest version is LEED V4.0 in 2014. LEED includes many subsystems.

3.1.3. Development process of CASBEE. The development of Japan's green building evaluation system has gone through three stages. The first stage of evaluation was the indoor construction environment to improve the user's comfort. In the second phase, the impact on the outdoor environment was added to
the evaluation system. The third stage created the building performance identification system, building energy saving identification system, building life certification system and green building certification system. CASBEE is supported by Ministry of Land Infrastructure and Transport. The first version was formally issued in 2002 to evaluate office buildings.

3.1.4. Development process of GBL. In contrast, China's green building evaluation standards started late. In 2001, Tsinghua University and other organizations compiled Manual for the Evaluation of Ecological Housing in China. Two years later, the Green Olympics Building Assessment System emerged. In March 2006, China issued assessment standard for green building evaluation standard. More than 20 local and industry standards of provinces were appeared afterwards. In 2014, ASGB adjusted according the problems appeared during past 8 years.

3.2. Evaluation objects

3.2.1. Evaluation objects of BREEAM. Based on BREEAM, there are 6 independent assessment standards, which are BREEAM New Construction, BREEAM In-Use, BREEAM Communities, Eco Homes, Code for Sustainable Homes, and BREEAM Refurbishment. BREEAM New Construction contains BREEAM Offices, BREEAM Courts, BREEAM Data Centers, BREEAM Education, BREEAM Healthcare, BREEAM Industrial, BREEAM Multi-residential, BREEM Prison and BREEAM Retail.

3.2.2. Evaluation objects of LEED. In LEED, there are 5 evaluation standards for the specific objects, which are LEED for building design and major renovations(LEED-BD+C), LEED for Interior design and construction(ID+C), LEED for building operations and maintenance(O+M), LEED for neighbourhood development(ND), LEED for homes(H) and LEED for cities and communities(CC).

3.2.3. Evaluation objects of CASBEE. CASBEE system is dived to 4 sub-systems, which are residential building system, construction system, urban community system and city system. The evaluation objects of residential building system could be new constructing or existing detached houses and new apartments. In construction system, the assessment objects are new construction, retrofitting building, heat island related building, temporary building and real estate evaluation building. CASBEE for new construction is for commercial building and non-commercial building, including public building and industry building.

3.2.4. Evaluation objects of GBL. GBL GB/T50378-2014 is suitable for evaluation of residential building and public building. The other assessment standards are customized for industry building, office building, hospital, campus, construction, green eco-community and retrofitted building. Table 2 shows evaluation objects of assessment standard for green building above all.

3.3. Evaluation indicators and weightings

3.3.1. Evaluation indicators and weightings of BREEAM. Taking BREEAM for new construction of non-domestic buildings 2018 1.0 (BREEN-NC-ND 2018) as example, the first level indicators are Management, Health and wellbeing, Energy, Transport, Water, Material, Waste, Land use and Ecology, Pollution, and Innovation (figure 1). The main output from a certified BREEAM assessment is the rating (table 3). A certified rating reflects the performance achieved by a project and its stakeholders, as measured against the standard and its benchmarks. Each of these categories addresses the most influential factors, including low impact design and carbon emissions reduction, design durability and resilience, adaption to climate change, and ecological value and biodiversity protection. Each section score equals percentage of credits achieved multiply by environmental section weightings. Section weightings are determined by assessment types, which are fully fitted, simple
building, shell & core only, and shell only (table 4). In the latest vision of BREEAM, some new icons have been designed to represent the information in the manual (figure 1 and figure 2).

Table 2. Evaluation objects of assessment standard for green building

| BREEAM-U.K. | LEED-U.S. | CASBEE-Japan | GBL-China |
|-------------|-----------|---------------|-----------|
| New construction | BREEAM for new construction | LEED for building design and major renovations | CASBEE for new construction | GBL for new construction |
| Retrofitting building | BREEAM for refurbishment | LEED for building energy efficiency and operations | CASBEE for refurbishment | GBL for new refurbishment |
| Existing buildings | BREEAM for reuse | LEED for building operations and maintenance | CASBEE for existing buildings | GBL for new construction (in operation) |
| Residential building | BREEAM for homes | LEED for homes | CASBEE for detached house, and residential building (hospital, hotel, apartment) | GBL for new construction |
| Public building | BREEAM for offices, courts, data centers, education, healthcare, multi-residential, prison, and retail | LEED for Schools, Retail, Hospitality, data centers, warehouses & distribution centers, and healthcare | CASBEE for non-residential building (office building, school, retail, restaurant, gym, commercial building, music hall etc.) | GBL for public building (office building, hospital, campus) |
| Community or city | BREEAM for communities | LEED for neighborhood development and cities & communities | CASBEE for communities and city development | GBL for eco-community |
| Industrial building | BREEAM for industrial | None | CASBEE for Non-residential building (industry building) | GBL for industrial building |
| Special building | None | None | CASBEE for heat island and real estate evaluation | None |

Table 3. BREEAM-NC 2018 rating benchmarks

| BREEAM Rating | Outstanding | Excellent | Very good | Good | Pass | Unclassified |
|---------------|-------------|-----------|-----------|------|------|--------------|
| Score (%)     | ≥ 85        | ≥ 70      | ≥ 55      | ≥ 45 | ≥ 30 | <30          |

Table 4. BREEAM environmental section weightings

| Environmental section | Fully fitted out | Assessment types of weighting |
|-----------------------|------------------|-------------------------------|
|                       | Simple building  | Shell and core only | Shell only |
| Management            | 11%              | 7.5%                    | 11%         | 13%        |
| Health and Wellbeing  | 14%              | 16.5%                   | 8%          | 7%         |
| Energy                | 16%              | 11.5%                   | 14%         | 9.5%       |
| Transport             | 10%              | 11.5%                   | 11.5%       | 14.5%      |
| Water                 | 7%               | 7.5%                    | 7%          | 3%         |
| Materials             | 15%              | 17.5%                   | 17.5%       | 22%        |
| Waste                 | 6%               | 7%                      | 7%          | 8%         |
| Land Use and Ecology  | 13%              | 15%                     | 15%         | 19%        |
| Pollution             | 8%               | 6%                      | 9%          | 6%         |
| Total                 | 100%             | 100%                    | 100%        | 100%       |
| Innovation (additional)| 10%             | 10%                     | 10%         | 10%        |
3.3.2. Evaluation indicators and weightings of LEED. In LEED-BD+C (new construction) V4.0, there are 7 aspects of first grade indexes (Table 5). They are location and transportation (LT), sustainable site (SS), water efficiency (WE), energy and atmosphere (EA), materials and resources (MR), indoor environment quality (EQ), innovation (IN), regional priority (RP), and integrative process (IP). According to the weight coefficient, EA ranks first. LT and EQ ties for second place. The total points is 110. LEED sets 4 rating levels, which are Certified, Silver, Gold, and Platinum.

| Items | Details and values |
|-------|-------------------|
| Indicators | EA | LT | EQ | MR | WE | SS | IN | RP | IP |
| Points | 33 | 16 | 16 | 13 | 11 | 10 | 6 | 4 | 1 |
| Ratios | 30% | 15% | 15% | 12% | 10% | 9% | 5% | 4% | 1% |
| Rating levels | Certified: 40-49 | Silver: 50-59 | Gold: 60-79 | Platinum: 70+ |

3.3.3. Evaluation indicators and weightings of CASBEE. According to the definition of Building Environmental Efficiency (BEE), the core concept of CASBEE, the evaluation index is divided into two major categories Q and L. In CASBEE-NC 2014, the indexes of environmental quality are quality of indoor environment (Q1), quality of service (Q2), and quality of outdoor environment on site (Q3). And the load of building environment indexes is energy load (LR1), resources load and material (LR2), and off-site environment (LR3) (Table 6). BEE equals (Q1 + Q2 + Q3) / (LR1 + LR2 + LR3).

| Items | Details and values |
|-------|-------------------|
| Indicators | Q1 | Q2 | Q3 | LR1 | LR2 | LR3 |
| Weightings | 0.4 | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 |
| Ranks | Excellent: BEE ≥ 3.0, Q ≥ 50 | Very good: BEE = 1.5–3.0 | Good: BEE = 1.0–1.5 | B+: BEE = 1.0–1.5 | B-: BEE = 0.5–1.0 | C: BEE < 0.5 |
| BEE value | Excellent | Very good | Good | B+ | B- | C |
| Expression | ★★★★★ | ★★★★★ | ★★★ | ★★★ | ★★ | ★ |

3.3.4. Evaluation indicators and weightings of GBL. The evaluation indicators include 7 sections, which are land saving (Q1), energy saving (Q2), water saving (Q3), material saving (Q4), indoor environmental...
quality (Q5), construction management (Q6), and operation management (Q7). Total score of each section is 100. A score of a section equals actual score is divided by total score excluding inapplicable items and then multiplied by 100. The weightings of sections are showed in table 7.

| Items | Details and values |
|-------|-------------------|
| Indicators | Q1 Q2 Q3 Q4 Q5 Q6 Q7 |
| Design assessment weightings | 0.16 0.28 0.18 0.19 0.19 0 0 |
| Operation assessment weightings | 0.13 0.23 0.14 0.15 0.15 0.10 0.10 |
| Rating level and score | 80 ★★★ | 60 ★★ | 50 ★ |

4. Conclusions and implications

Typical green building evaluation systems are compared. In terms of green building concept, all the evaluation systems emphasize creating a built environment based on reducing environmental impact. The evaluation targets mainly in residential and public buildings, lacking of industrial construction evaluation. The indicators are mainly energy, resources, environment, design and operation management. According to the importance, index weight coefficients are determined.

The implications found from comparative studies are as follow.

- Maintain the dynamic development of the evaluation system
  Economic and technological development has an impact on green buildings. The evaluation system should be adjusted as the environment changes. The evaluation content related to new products and technologies should be increased timely.
- Increase the flexibility of the evaluation system based on accuracy
  The impact of buildings on the environment is influenced by many factors such as building functions, climate and environment, and service objects. The evaluation system should have the flexibility to adapt to the needs of different evaluation objects.
- Pay attention to the influence of human factors on green buildings
  Architecture is the artificial environment that humans create in nature. Therefore, the influence of the human factor in it cannot be ignored. The purpose of the green building evaluation system is to guide the harmonious coexistence of architecture and the environment. Evaluation indicators represent the advocated development direction.

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