

Article

# A Comprehensive Analysis: Sustainable Trends and Awarded LEED 2009 Credits in Vietnam

Duy Hoang Pham <sup>1</sup>, Byeol Kim <sup>1</sup>, Joosung Lee <sup>2,\*</sup>, Abraham Chiwon Ahn <sup>3</sup> and Yonghan Ahn <sup>4,\*</sup>

<sup>1</sup> Department of Architectural Engineering, Hanyang University, 55 Hanyangdaehak-ro, Sangrok-gu, Ansan-si, Gyeonggi-do 15588, Korea; phamduyhoang@hanyang.ac.kr (D.H.P.); keemstars@naver.com (B.K.)

<sup>2</sup> Innovative Durable Building and Infrastructure Research Center, Hanyang University, 55 Hanyangdaehak-ro, Sangrok-gu, Ansan-si, Gyeonggi-do 15588, Korea

<sup>3</sup> Department of Architectural Design, Hanyang University, 55 Hanyangdaehak-ro, Sangrok-gu, Ansan-si, Gyeonggi-do 15588, Korea; abeahn@hanyang.ac.kr

<sup>4</sup> School of Architecture and Architectural Engineering, Hanyang University, 55 Hanyangdaehak-ro, Sangrok-gu, Ansan-si, Gyeonggi-do 15588, Korea

\* Correspondence: js4ever@hanyang.ac.kr (J.L.); yhahn@hanyang.ac.kr (Y.A.)

Received: 20 December 2019; Accepted: 20 January 2020; Published: 23 January 2020



**Abstract:** Established by the U.S. Green Building Council (USGBC), the Leadership in Energy and Environmental Design (LEED) became a sustainable leader of green building rating systems in American and many other countries. In Vietnam, LEED is expected as a potential solution in improving the sustainable quality of buildings for residents and solving the housing/infrastructure demand with a limit in resource consumption and minimizing negative environmental impacts. The study analyzed the awarded LEED 2009 credits by investigating the data of 36 of the total 42 LEED BC+D 2009 certified projects in Vietnam. The results of the investigation indicated the awarded credits were significantly implemented in Vietnam. These results were converted based on the summary updated on LEED version 4 of the USGBC report, to become a useful guideline for green building cost-efficiency strategies. Additionally, it also served as reference data for the Vietnamese public agency to update their green regulations based on the specific characteristics of Vietnam.

**Keywords:** sustainability; green building; LEED; Vietnam

## 1. Introduction

Besides the rapid economic growth, environmental pollution and the lack of housing demand, the research of sustainability has become a top concern for developing countries [1]. Especially in 2019, the study of Climate Central showed that a large area of Vietnam could be drowned due to rising sea levels in 2050, and a quarter of Vietnam's population will be profoundly affected by climate change [2]. Along with the limitations of developing countries such as seeking large budgets to address environmental issues, it is essential and necessary to find a way to promote sustainable development. Obviously, the construction industry not only accounts for a large proportion of Vietnam's production, but buildings also contribute a large part to the consumption of electricity, water, and other research resources [3]. Thus, green buildings had flourished in recent years after recognizing their potential social and economic benefits in solving many negative environmental issues and problems [4]. Moreover, the increase in electricity prices and recent urban environment incidents in Vietnam also became a strong motivation for real estate developers to choose green building certification for their future projects [1,3]. This trend can be reflected by the increase in the number of projects participating in green building certification in Vietnam in recent years, especially LEED certificates with notable numbers.

LEED and other green building certification systems provided technical guides and a framework to promote sustainable construction practical activities by balancing the elements of environmental protection, energy/water consumption, the benefits of user and community and operations, and maintenance solutions [3,5]. While promoting sustainable construction and bringing many benefits to building residents and the community, several problems related to the applying of LEED are also identified [6], such as encountering challenges for the project team and cost increasing [3]. Considerable challenges of implementing a LEED building project were the expensive quests, higher construction cost [7] and non-experience extra works for the construction team [5]. The additional charges might come from hiring LEED consultants, Commissioning Authority (CxA), air-testing and flush-out test contractors [8], which are entirely unfamiliar and expensive to the Vietnamese building project [3]. However, several studies indicated that LEED projects may have little incremental costs (2.5 to 9.4%) but will significantly reduce the operating costs (about 31%) of the building [9]. The study by D. Langdon (2007) and J.O. Choi (2015) also confirmed that this cost impact could be completely limited by their previous similar project experience and commitment during project implementation [5,10]. The research of Y.H. Ahn (2015) showed that it is crucial to apply the Integrated Construction Process (ICP) to collect the knowledge and ideas of all key stakeholders for successfully implementing green buildings with an acceptable cost [4].

In addition, C.P. Cheng's (2015) study mentioned that the better judgment of target credit selection and the appropriate green design technologies largely depend on the experience of managers from previous LEED projects [11]. However, construction projects are unique, and it is often difficult to participate in similar projects, especially when the number of certified LEED projects is very limited in Vietnam at present. Besides that, the new projects applying for LEED certification form 2018 have to comply with the unique requirements of LEED version 4 with many considerable changes, which might create several difficulties for the project team [3]. As a result, a useful guide for the green building project in selecting LEED credits that are appropriate to the project goals, from the synthesis and analysis of previous projects, would bring many significant benefits to the LEED projects and promote the sustainable construction. Thus, this study was conducted to create a useful guideline for the project and building developer for identifying the suitable project LEED credits/goals and its risk by investigating and analyzing all similar projects that have received LEED certification in Vietnam. This paper aims to:

- (1) Identify the significantly awarded credits at LEED projects in Vietnam.
- (2) Investigate the significant different credits between the different LEED certificate levels and provide the recommendations for credits required for future LEED projects.
- (3) Review and summarize the significant differences between LEED 2009 and LEED v4 to combine with the analysis results and make more suitable guidelines and recommendations.

## 2. Literature Review

### 2.1. Background of Research

"The most widely used green building rating system in the world," "The framework to create healthy, highly efficient and cost-saving green buildings," and "The globally recognized symbol of sustainability achievement" are the definitions of the U.S. Green Building Council (USGBC) about the "Leadership in Energy and Environmental Design" (LEED) rating system [8]. Additionally, LEED is the meaningful attempt of USGBC to create a global rating system, which guides technically to design and deliver the green building. Thus, green building projects that comply with the LEED requirement not only promote sustainable construction but also increase the project life cycle cost-effective health benefits to users [3,6,12]. LEED is considered as the most globally popular green building rating tool because of its overlooked variations between different climatic and environmental conditions, rules, standards, and laws. The selection of LEED credits dramatically affects the results of the project, but it is more difficult due to the rising tide of cost, schedule, and LEED experience. Thus, understanding

the relationships between decision-making factors and characteristics of LEED on various credits is essential for project stakeholders and regulatory authorities [3,6]. As a result, many pieces of research are conducted to guide better efficiency of the green building projects and encourage sustainable construction. In particular, a significant number of them were conducted to support the design process and identify appropriate LEED credits for the project during the early phase, when the design changes are much higher in efficiency and less costly [3,4].

Cheng and Ma (2015) studied the relationship between LEED credits and green building technologies/sustainability design strategies to improve the effectiveness of LEED credits selection [11]. M.A. Jun's paper (2015) presented a methodology for identifying the target LEED credits based on project information and climatic factors [13]. J. Ma's study (2016) analyzed LEED credit achievements in previous projects using data-driven techniques and provided useful instruction so as to help the project team to understand and identify the appropriate LEED credits [14]. Jack C.P. Cheng's paper (2015) proposed a case-based reasoning (CBR) approach to find out the suitable case study base on the similar previously certificated green building projects and suggestions on target LEED credits [11]. F. Jalaei and A. Jrade's study (2015) (BIM) explains how this integration would assist project teams in making sustainability-related decisions [15]. P.H. Chen and T.C. Nguyen developed an application by interacting web map service (WMS) technology and BIM to pre-calculate LEED awarded points of the "Location and transportation" category [16]. The research of S. Pushkar (2018) pointed out that several data analysis studies of previous LEED-certified projects have to consider the problem of pseudoreplication [17]. Recently, when Wu et al. (2017) [6] and Wu et al. (2018) [18] analyzed previous LEED certification project data, they used aggregated processes to achieve extremely low P-values. Da Silva and Ruwanpura (2009) investigated LEED Canada certificated building data and found out that material (MR) and energy and atmosphere (EA) criteria are not common at LEED projects in Canada [19]. Cell and Beata (2009) presented that the lack of consideration in the design phase of a green building project may have an adverse impact on the implementation phase [20]. J.-Y. Park's study (2017) developed an optimization algorithm that aims to determine the LEED awarded points that can be achieved with minimum cost [12]. Madanayake and Ruwanpura (2012) suggested a method for determining appropriate LEED credits based on cost, productivity, and environmental impact information [21]. Juan, Gao, and Wang (2010) addressed a selection of green building technology strategies by optimizing the trade-off between costs and achievements in different green building rating systems [22]. Castro-Lacouture, Sefair, Flórez, and Medaglia studied the factors influencing the selection of sustainable materials in the LEED project [23]. Boschmann and Gabriel proposed (2007) the implementation and development of green technologies directly related to a particular LEED credit [24]. Pushkar (2018) identified the significant differences in the choice of implementing LEED credits among several countries, including SS, WE, EA, EQ, and ID [25]. In other words, it is highly useful for analyzing the influence and development of green buildings in developed countries to benchmark the Green Building regulation system of developing countries [26].

In summary, the previous studies have provided the LEED credits choosing by using various methods of selection supporting the appropriate credit through the assistance of BIM, available previous LEED building data, or decision-making strategies technic and so on. However, there is no previous study which offers limited guidance for developing countries like Vietnam. Therefore, an analysis of certified LEED projects is needed to promote the development of sustainable construction in Vietnam by providing direction of goal-setting to designers and developers. In addition, the developers of the Vietnam Green Building Council also have grounds to adjust their policies more appropriately for promoting sustainable construction in Vietnam.

## 2.2. Comparison of LEED 2009 and LEED Version 4

Every few years, the USGBC offers a new version of LEED to capture new trends in the construction industry, and embraces new opportunities for encouraging sustainable construction. [27]. There are several versions of LEED being used in Vietnamese existing buildings, but the 2009 LEED version

has occupied for the majority of current certified projects and is applied to projects registered before 2018. The previous versions of LEED, which are LEED v2.2 and LEED 2009, both have six main categories, including sustainable sites (SS), the water efficiency (WE), the energy and atmosphere (EA), the material and resources (MR), the indoor environmental quality (IEQ), and the innovation in design (ID) [6,25]. LEED 2009 consists of 6 major sets of criteria with 12 prerequisite credits and 42 optional credits, and credits also have different performance strategies [11]. The newer version is the LEED v4 and LEED v4.1 that was announced in 2014 and mandatorily applied to all newly registered projects from 2018 [8]. Currently, most current projects in Vietnam are certified LEED 2009, while new projects need to comply with LEED v4 requirements. To apply for future projects, the results of this analysis should be considered by checking the differences between LEED 2009 and LEED v4.

The updated version, LEED v4, still has the same total score (110 pts), but the SS (26 pts) criteria group is divided into two smaller criteria groups, which are “Location and Transportation (LT)” (16 pts) and SS (10 pts) [8,25,28]. The updated Location and Transportation criteria were published in LEED v4, including some Sustainable Site credits of LEED 2009, such as protection and green transportation parking, land usage and so on. Meanwhile, the new SS criteria group includes light pollution reduction, site usage and protection, rainwater, and heat island credits [28]. In fact, the assessment of SS issues is very similar to the assessment of LT+SS issues [25]. In LEED v4 EA, MR, EQ criteria, credits are still included as in LEED 2009 but there are some changes in the detailed requirements and more recommended green strategies [28]. Only one new credit, acoustic performance, was introduced in the LEED NCv4 [25]. According to the USGBC report [28], although there is not much change in the score distribution between categories, several credits have been added and some of its requirements have been majorly changed in the new version. Svetlana Pushkar’s research evaluates that the majority of LEED version 4 is similar to the previous LEED 2009 and that it is feasible to modify the algorithm for LEED v4 extended credits [25].

### 3. Research Method

#### 3.1. Scope of the Study

The objective of the study is investigating LEED-certified buildings data to find the association between each LEED credits compliance performance and LEED certificate targeted level of the project. From the results, we provided a guideline to the project team in making decisions on their green strategies and the LEED credits decision that will be more cost-effective. The study also aims to identify differences in green building projects in Vietnam and other developed countries as a basis for adjusting Vietnam’s existing green building standards such as LOTUS (Vietnam Green Building Council) and TCVN 09-2017 (Vietnam Ministry of Construction). Therefore, the population of the study is all LEED projects in Vietnam, but the number of projects is minimal and mostly LEED NC projects. The target of this study is collecting and analyzing all existing LEED NC projects (November 2019). Furthermore, similar to the other countries’ conditions, the number of LEED v4 projects in Vietnam is also minimal [3], so data of the research is obtained from LEED 2009 projects in Vietnam.

#### 3.2. Data Collection

Project data was collected from the official website of the U.S, Green Building Council. In an effort to promote and disseminate the LEED standard system globally, the USGBC has published numerous documents as well as data on their successful projects. At the time of the study, a total of 42 LEED 2009 NC projects were certified, of which only 36/42 projects had complete data on the credits received. Despite the limited number of samples, the study was conducted over the entire population, and the statistical results of the data were accepted as a normal distribution according to the central limit principle [29] (p. 208).

### 3.3. Characteristics of the Vietnamese Green Building

Factors of project characteristics, location, and climate are critical to the selection of appropriate investment strategies. The average annual temperature in Vietnam is from 22 °C to 27 °C. Every year, there are about 100 rainy days with an average rainfall of 1500 mm to 2000 mm and the air humidity is around 80% [30]. The majority of projects (28/36) investigated in this study are located in the southern part of Vietnam, which has a humid tropical climate with a low amplitude of heat fluctuation during the year, with high temperature and humidity. Therefore, most LEED projects are not equipped with heating equipment. Furthermore, these projects are also mainly factory projects or office buildings, where the developer is responsible for operating their project, and the energy-saving strategies bring direct efficiency to their operating costs. Post-tropical humid weather with heavy rainfall and the diversity of native species also offer many advantages in developing LEED strategies related to greenery and irrigation. The sunshine hours in many areas of Vietnam are quite high, with the number of sunshine hours being about 1500–2000 h [30]; also, the average annual radiant heat is 100 kcal/cm<sup>2</sup> which provides many advantages for solar energy solutions. However, similar to many developing countries, the shortage of various green materials also makes it more difficult to implement LEED credits for material criteria.

### 3.4. Data Analysis

In this study, 2009 LEED credits are divided into two groups for analysis due to their characteristics. The first group is the credits that only awarded a maximum of 1 point, meaning that the project team can only decide to implement or not. The research will then investigate the credit of group 1 based on the frequency of awarded credits for LEED-certified projects in Vietnam. In the second group, the number of points awarded per credit is greater than 2, and the project may achieve different levels of compliance to request based on the project's conditions. For group 2, the credit achievement degree (CAD) will be revised from W. Peng's (2017) [6] study, and be calculated based on the following Equation (1):

$$CAD = \frac{PCO}{TPC} \times 100\% \quad (1)$$

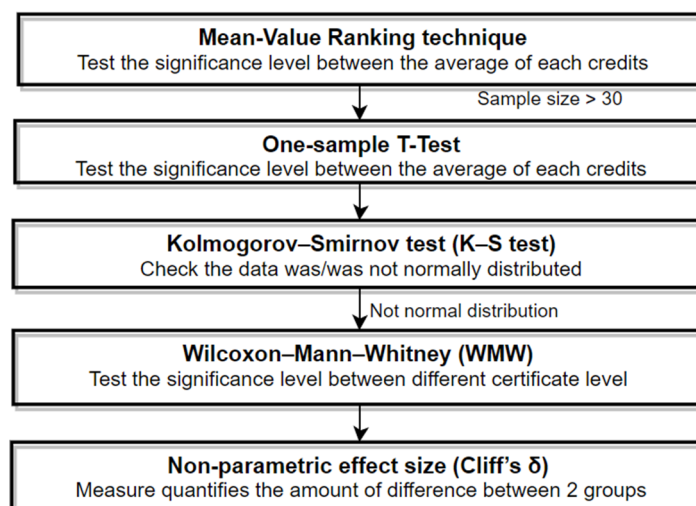
where CO is the point that credit obtained and TC equals to total points of credits. As such, the CAD represents the level of fulfillment of LEED's requirements.

In this study, the statistical tests used to analyze LEED awarded credits from collected data include the Mean-Value Ranking test, One-sample *t*-test, Kolmogorov–Smirnov test, Wilcoxon–Mann–Whitney and non-parametric effect size index (Figure 1). At first, in order to identify common LEED credits, the study conducted the ranking techniques for first and second group credits. In the second step, the One-sample *t*-test was used to determine the significant LEED awarded credits in the previous Vietnamese LEED projects. The given hypothesis H0 is “the frequency of awarded credit is less than 50% in the Vietnamese LEED projects” with the confident index of 95%. In the third step, the normal distribution test is implemented because the number of samples of LEED silver, gold LEED, and LEED platinum projects is limited. Furthermore, the results of the Kolmogorov–Smirnov test showed that data is not a normal distribution, and LEED data are presented in ordinal scales [17]. To investigate the significant differences between the two groups with different LEED certificate levels of certification and consider the problem of pseudoreplication, the statistical tests used are based on suggestions of S. Pushkar's (2018) study [25]. Following the non-parametric tests of S. Pushkar's (2018) study, Cliff's  $\delta$  and WMW tests [29] were used to compare the two unpaired groups. The data are presented as the median  $\pm$  interquartile range (IQR, 25th–75th percentile) [17]. Cliff's  $\delta$  is used to measure the substantive significance (effect size) between two non-paired groups. Cliff's  $\delta$  [31] (p. 495) is calculated following Equation (2) where  $x_1$  and  $x_2$  are the points in 2 compared groups respectively;  $n_1$  and  $n_2$  are the sizes of the sample groups, and  $\#$  is the index times. The WMW test was used to determine the statistical difference between the two unpaired groups. It should be noted that WMW tests can be



applied in two forms: approximate or extracted. If the sample size is more than 9, an approximate WMW test has been used, and the extracted form for all else [32] (p. 56).

$$\delta = \#(x_1 > x_2) - \#(x_1 < x_2)/(n_1n_2) \quad (2)$$



**Figure 1.** The summary of the data analysis test framework of the study.

Finally, the Neo-Fisherian significance assessments (NFSAs) are used to interpret the signs and magnitudes of the statistical effects [17]. Based on NFSAs, precise P-values were evaluated and shown according to a three-valued logic as follows:

- “Positive”: The credit seems to be a difference between two compared groups.
- “Negative”: The credit does not seem to be a difference between two compared groups.
- “Suspended”: The credit regards the difference between two compared groups.

## 4. Results

### 4.1. The Popularly Awarded LEED Credits in the Vietnamese Projects

The critical objective of this study is to investigate the credits that are commonly implemented at LEED projects in Vietnam. As a result, the study suggested a list of LEED credits that should be considered for future projects, which were shown through the analyzed result of ranking Technic methods (in Table 1) and *t*-test (in Table 2). Please see the detailed description of the LEED credits and the corresponding symbol in Appendix A.

As mentioned above, the 1st group are the credits that the project can only achieve or not. Thus, the result of ranking technics of the 1st group, which were shown in Table 1, illustrated the ranking based on credits' frequency. If the credits' frequency is similar, the credits have a smaller standard deviation index that would be prioritized. Similar to the first group, Table 2 showed the ranking of the second group of LEED credits based on the CAD index; the average points the creditors have set are also presented. At LEED projects in Vietnam, the most popular 1st group credits include IDc2 (97.22%), EQc4.2 (94.44%), and SSc1 (91.64%) compared to the opposite side of rarely awarded credits such as SSc3 (0%), MRc6 (0%), and MRc7 (0%). In the second group of credits, the high popularity credits are SSc4.3 (100%), SSc4.4 (97.22%), MRc5 (94.44%), WEc3 (93.75%), and WEc2 (91.67%), and the low popularity credits were MRc1 (10.19%), and MRc3 (0%). We suggested that the inexperienced LEED project teams should select the credits to consider for their projects based on the rankings in Table 1.

**Table 1.** (a) Ranking the popularity of 1st group LEED credits in Vietnam; (b) ranking the popularity of 2nd group LEED credits in Vietnam.

Rank	ID	Points	Frequency	STD	Rank	ID	Points	Frequency	STD
1	IDc2	1	97.22	16.67	16	EQc3.2	1	36.11	48.71
2	EQc4.2	1	94.44	23.23	17	SSc5.1	1	33.33	47.81
3	SSc1	1	91.67	28.03	18	SSc6.2	1	33.33	47.81
4	EQc3.1	1	88.89	31.87	19	EQc4.4	1	30.56	46.72
5	SSc7.1	1	86.11	35.07	20	EQc7.1	1	30.56	46.72
6	SSc4.2	1	83.33	37.80	21	EQc7.2	1	27.78	45.43
7	SSc7.2	1	80.56	40.14	22	SSc6.1	1	25.00	43.92
8	EQc4.3	1	77.78	42.16	23	EQc1	1	22.22	42.16
9	EQc4.1	1	72.22	45.43	24	EQc5	1	19.44	40.14
10	SSc5.2	1	69.44	46.72	25	EQc6.2	1	5.56	23.23
11	EQc2	1	63.89	48.71	26	MRc1.2	1	2.78	16.67
12	EQc6.1	1	52.78	50.63	27	SSc3	1	0.00	0.00
13	EQc8.1	1	50.00	50.71	28	MRc6	1	0.00	0.00
14	SSc8	1	41.67	50.00	29	MRc7	1	0.00	0.00
15	EQc8.2	1	38.89	49.44					

(a)

Rank	ID	Max Points	CAD Mean	Ave. Points	STD	Rank	ID	Max Points	CAD Mean	Ave. Points	STD
1	SSc4.3	3	100.00	3.00	0.00	11	IDc1	3	72.22	2.17	22.57
2	SSc4.4	2	97.22	1.94	16.67	12	EAc3	2	69.44	1.39	46.72
3	MRc5	2	94.44	1.89	23.23	13	EAc4	2	69.44	1.39	46.72
4	WEc3	4	93.75	3.75	15.09	14	EAc1	19	53.36	10.14	30.85
5	WEc2	2	91.67	1.83	28.03	15	SSc2	5	27.78	1.39	45.43
6	WEc1	4	87.50	3.50	21.96	16	EAc2	7	25.00	1.75	41.03
7	MRc2	2	80.56	1.61	38.32	17	EAc6	2	19.44	0.39	40.14
8	MRc4	2	80.56	1.61	38.32	18	MRc1.1	3	10.19	0.31	29.62
9	SSc4.1	6	80.56	4.83	40.14	19	MRc3	2	0.00	0.00	0.00
10	EAc5	3	80.56	2.42	40.14						

(b)

**Table 2.** The results of the normal distribution test and one-sample *t*-test.

1st Group					2nd Group				
ID	N	Frequency	<i>p</i> -Value	Sig. Value	ID	N	CAD Mean Value	<i>p</i> -Value	Sig. Value
SSc1 *	36	91.67	0.000 <sup>a</sup>	0.000 <sup>c</sup>	SSc2	36	27.78	0.000 <sup>a</sup>	0.000 <sup>c</sup>
SSc3	36	0	- <sup>b</sup>	- <sup>b</sup>	SSc4.1	36	80.56	0.000 <sup>a</sup>	0.412
SSc4.2 *	36	83.33	0.000 <sup>a</sup>	0.000 <sup>c</sup>	SSc4.3 *	36	1000.00	- <sup>b</sup>	- <sup>b</sup>
SSc5.1	36	33.33	0.000 <sup>a</sup>	0.044	SSc4.4 *	36	97.22	0.000 <sup>a</sup>	0.000 <sup>c</sup>
SSc5.2 *	36	69.44	0.000 <sup>a</sup>	0.017 <sup>c</sup>	WEc1 *	36	87.50	0.000 <sup>a</sup>	0.002 <sup>c</sup>
SSc6.1	36	25	0.000 <sup>a</sup>	0.002 <sup>c</sup>	WEc2 *	36	91.67	0.000 <sup>a</sup>	0.001 <sup>c</sup>
SSc6.2	36	33.33	0.000 <sup>a</sup>	0.044 <sup>c</sup>	WEc3 *	36	93.75	0.000 <sup>a</sup>	0.000 <sup>c</sup>
SSc7.1 *	36	86.11	0.000 <sup>a</sup>	0.000 <sup>c</sup>	EAc1 *	36	53.36	0.063	0.000 <sup>c</sup>
SSc7.2 *	36	80.56	0.000 <sup>a</sup>	0.000 <sup>c</sup>	EAc2	36	250.00	0.000 <sup>a</sup>	0.000 <sup>c</sup>
SSc8	36	41.67	0.000 <sup>a</sup>	.324	EAc3	36	69.44	0.000 <sup>a</sup>	0.480
MRc1.2	36	2.78	0.000 <sup>a</sup>	0.000 <sup>c</sup>	EAc4	36	69.44	0.000 <sup>a</sup>	0.480
MRc6	36	0	- <sup>b</sup>	- <sup>b</sup>	EAc5	36	80.56	0.000 <sup>a</sup>	0.412
MRc7	36	0	- <sup>b</sup>	- <sup>b</sup>	EAc6	36	19.44	0.000 <sup>a</sup>	0.000 <sup>c</sup>
EQc1	36	22.22	0.000 <sup>a</sup>	0.000 <sup>c</sup>	MRc1.1	36	10.19	0.000 <sup>a</sup>	0.000 <sup>c</sup>
EQc2	36	63.89	0.000 <sup>a</sup>	0.096	MRc2	36	80.56	0.000 <sup>a</sup>	0.390
EQc3.1 *	36	88.89	0.000 <sup>a</sup>	0.000 <sup>c</sup>	MRc3	36	00.00	- <sup>b</sup>	- <sup>b</sup>
EQc3.2	36	36.11	0.000 <sup>a</sup>	0.096	MRc4	36	80.56	0.000 <sup>a</sup>	0.390
EQc4.1 *	36	72.22	0.000 <sup>a</sup>	0.006 <sup>c</sup>	MRc5 *	36	94.44	0.000 <sup>a</sup>	0.000 <sup>c</sup>

Table 2. Cont.

1st Group					2nd Group				
ID	N	Frequency	p-Value	Sig. Value	ID	N	CAD Mean Value	p-Value	Sig. Value
EQc4.2 *	36	94.44	0.000 <sup>a</sup>	0.000 <sup>c</sup>	IDc1	36	72.22	0.004 <sup>a</sup>	0.465
EQc4.3 *	36	77.78	0.000 <sup>a</sup>	0.000 <sup>c</sup>	SSc2	36	27.78	0.000 <sup>a</sup>	0.000 <sup>c</sup>
EQc4.4	36	30.56	0.000 <sup>a</sup>	0.017 <sup>c</sup>	SSc4.1	36	80.56	0.000 <sup>a</sup>	0.412
EQc5	36	19.44	0.000 <sup>a</sup>	0.000 <sup>c</sup>	SSc4.3 *	36	1000.00	- <sup>b</sup>	- <sup>b</sup>
EQc6.1	36	52.78	0.000 <sup>a</sup>	0.744	SSc4.4	36	97.22	0.000 <sup>a</sup>	0.000 <sup>c</sup>
EQc6.2	36	5.56	0.000 <sup>a</sup>	0.000 <sup>c</sup>	WEc1	36	87.50	0.000 <sup>a</sup>	0.002 <sup>c</sup>
EQc7.1	36	30.56	0.000 <sup>a</sup>	0.017 <sup>c</sup>	WEc2	36	91.67	0.000 <sup>a</sup>	0.001 <sup>c</sup>
EQc7.2	36	27.78	0.000 <sup>a</sup>	0.006 <sup>c</sup>					
EQc8.1	36	50	0.000 <sup>a</sup>	10.000					
EQc8.2	36	38.89	0.000 <sup>a</sup>	0.186					
IDc2 *	36	97.22	0.000 <sup>a</sup>	0.000 <sup>c</sup>					

<sup>a</sup> The Kolmogorov–Smirnov test *p*-value is less than 0.05. <sup>b</sup> The Standard deviation = 0, the Kolmogorov–Smirnov test and *t*-test could not be calculated. <sup>c</sup> The *t*-test *p*-value is less than 0.05. \* The awarded credits with a significant popular rate in Vietnam.

As shown in Table 2, the results of the Kolmogorov–Smirnow test determine that most of the data collected are not a normal distribution. Therefore, the *t*-test is only performed for the whole sample (number of samples >30), and its results are also presented in Table 2. The *t*-test was conducted to identify the significantly awarded credits at LEED projects in Vietnam with a comparative value of 50%, and 95% of the confident index was set. The results of significantly awarded credits at LEED projects in Vietnam are:

- First group: SSc1, SSc4.2, SSc5.2, SSc7.1, SSc7.2, EQc3.1, EQc4.1, EQc4.2, EQc4.3, IDc2.
- Second group: SSc4.3, SSc4.4, WEc1, WEc2, WEc3, EAc1, MRc5.

#### 4.2. The Difference between LEED Project Target Goal Levels

USGBC classifies buildings by four levels of LEED certification, including LEED certified, LEED Silver, LEED Gold, and LEED Platinum. The higher the certification level, the more the project has to comply with LEED's strict requirements, which means they have to spend more on sustainable investments and additional work. Investigation of LEED credits that differ between these different project groups on project goals is based on the results of the Wilcoxon–Mann–Whitney test and the Cliff's delta values. The approximate WMW test results and Cliff's delta values of LEED credits between the groups of silver LEED and gold LEED projects ( $n = 12$ ) are shown in Tables 3a and 4a. Similarly, Tables 3b and 4b presented the results of the extract WMW test and Cliff's delta between the groups of the LEED gold and LEED platinum projects ( $n = 7$ ).



**Table 3.** The results of the Wilcoxon–Mann–Whitney test and Cliff’s delta indexes for the 1st group credits. (a) Between the groups of LEED Silver and LEED Gold certification projects; (b) between the groups of LEED Gold and LEED Platinum certification projects.

(a) LEED Silver vs. LEED Gold					(b) LEED Gold vs. LEED Platinum				
ID	n	Sig.	Cliff’s Delta	NFSAs	ID	n	Sig.	Cliff’s Delta	NFSAs
SSc1	12	0.317	0.083	Negative	SSc1	7	0.530	0.143	Negative
SSc3	12	1.000	0.000	Negative	SSc3	7	1.000	0.000	Negative
SSc4.2	12	0.356	0.167	Negative	SSc4.2	7	0.023	−0.571	Positive
SSc5.1	12	0.356	−0.167	Negative	SSc5.1	7	0.122	−0.429	Suspended
SSc5.2	12	.688	−0.083	Negative	SSc5.2	7	0.060	−0.429	Suspended
SSc6.1	12	0.356	0.167	Negative	SSc6.1	7	0.530	0.143	Negative
SSc6.2	12	1.000	0.000	Negative	SSc6.2	7	0.530	−0.143	Negative
SSc7.1	12	0.284	−0.167	Negative	SSc7.1	7	1.000	0.000	Negative
SSc7.2	12	0.028	0.417	Positive	SSc7.2	7	0.023	−0.571	Positive
SSc8	12	0.105	−0.333	Suspended	SSc8	7	0.591	0.143	Negative
MRC1.2	12	0.317	−0.083	Negative	MRC1.2	7	1.000	0.000	Negative
MRC6	12	1.000	0.000	Negative	MRC6	7	1.000	0.000	Negative
MRC7	12	1.000	0.000	Negative	MRC7	7	1.000	0.000	Negative
EQc1	12	1.000	0.000	Negative	EQc1	7	0.141	−0.286	Suspended
EQc2	12	1.000	0.000	Negative	EQc2	7	0.591	−0.143	Negative
EQc3.1	12	0.070	0.250	Suspended	EQc3.1	7	1.000	0.000	Negative
EQc3.2	12	0.105	0.333	Suspended	EQc3.2	7	0.530	−0.143	Negative
EQc4.1	12	0.028	−0.417	Positive	EQc4.1	7	1.000	0.000	Negative
EQc4.2	12	0.148	0.167	Suspended	EQc4.2	7	1.000	0.000	Negative
EQc4.3	12	0.140	−0.250	Suspended	EQc4.3	7	1.000	0.000	Negative
EQc4.4	12	0.660	0.083	Negative	EQc4.4	7	0.606	−0.143	Negative
EQc5	12	0.032	0.333	Positive	EQc5	7	0.141	−0.286	Suspended
EQc6.1	12	0.418	−0.167	Negative	EQc6.1	7	0.107	−0.429	Suspended
EQc6.2	12	0.317	0.083	Negative	EQc6.2	7	0.317	−0.143	Negative
EQc7.1	12	0.187	0.250	Suspended	EQc7.1	7	0.141	−0.286	Suspended
EQc7.2	12	0.356	0.167	Negative	EQc7.2	7	0.141	−0.286	Suspended
EQc8.1	12	0.000	−0.750	Positive	EQc8.1	7	0.060	0.429	Suspended
EQc8.2	12	0.216	−0.250	Negative	EQc8.2	7	0.254	0.286	Negative
IDc2	12	0.317	−0.083	Negative	IDc2	7	1.000	0.000	Negative

**Table 4.** The results of the Wilcoxon–Mann–Whitney test and Cliff’s delta indexes for the 2nd group credits. (a) Between the groups of LEED Silver and LEED Gold certification projects; (b) between the groups of LEED Gold and LEED Platinum certification projects.

(a) LEED Silver vs. LEED Gold					(b) LEED Gold vs. LEED Platinum				
ID	n	Sig.	Cliff’s Delta	NFSAs	ID	n	Sig.	Cliff’s Delta	NFSAs
SSc2	12	0.356	−0.167	Negative	SSc2	7	0.591	−0.143	Negative
SSc4.1	12	0.623	−0.083	Negative	SSc4.1	7	1.000	0.000	Negative
SSc4.3	12	1.000	0.000	Negative	SSc4.3	7	1.000	0.000	Negative
SSc4.4	12	0.317	0.083	Negative	SSc4.4	7	1.000	0.000	Negative
WEc1	12	0.065	−0.333	Suspended	WEc1	7	0.317	0.143	Negative
WEc2	12	0.070	−0.250	Suspended	WEc2	7	1.000	0.000	Negative
WEc3	12	0.654	−0.076	Negative	WEc3	7	0.142	−0.286	Suspended
EAc1	12	0.011	−0.611	Positive	EAc1	7	0.020	−0.735	Positive
EAc2	12	0.776	0.049	Negative	EAc2	7	0.001	−1.000	Positive
EAc3	12	0.680	0.083	Negative	EAc3	7	0.141	−0.286	Suspended
EAc4	12	1.000	0.000	Negative	EAc4	7	0.530	0.143	Negative
EAc5	12	0.356	−0.167	Negative	EAc5	7	0.317	−0.143	Negative
EAc6	12	0.284	−0.167	Negative	EAc6	7	0.530	−0.143	Negative
MRC1.1	12	0.482	−0.097	Negative	MRC1.1	7	0.317	0.143	Negative
MRC2	12	0.683	−0.069	Negative	MRC2	7	0.872	−0.041	Negative
MRC3	12	1.000	0.000	Negative	MRC3	7	1.000	0.000	Negative
MRC4	12	0.638	−0.090	Negative	MRC4	7	0.142	−0.286	Suspended
MRC5	12	1.000	0.000	Negative	MRC5	7	0.317	−0.143	Negative
IDc1	12	0.738	0.076	Negative	IDc1	7	0.030	−0.633	Positive

The summary of results of Tables 3a and 4a, which were the result of comparing two groups of LEED Silver projects and the group of LEED Gold projects showed the five credits had significant differences, including SSc7.2, EQc4.1, EQc 5, EQc 8.1, and EAc1. In addition, other credits have the “suspended” status, such as SSc8, EQc3. 1, EQc3.2, EQc4.2, EQc4.3, etc., can be considered as a secondary choice for getting the LEED Gold certificate. When comparing the difference in credits achievement between the LEED Gold projects group and the LEED Platinum projects group, Tables 3b and 4b illustrated the five credits which were identified with significant differences, including SSc4.2, SSc7.2, EAc1, EAc2, and IDc1. The credits SSc5.1, SSc.2, EQc1, EQc5, etc., were also considered for the second choice for getting the LEED Platinum certificate. When comparing Tables 3 and 4, there were some duplicated credits such as EAc1, EQc5, EQc7.1, EQc7.1, EQc8.1, and SSc7.2. These credits are all part of the second set of credits, so project teams need to consider the different levels of achievement of these credits to achieve higher levels of credits.

## 5. Discussion

### 5.1. Comparison with the Well-Developed Countries

Table 5 is referenced from Jae-Yong Park’s study (2017), and compared with the results of this study, the following points should be noted. The popular LEED credits of Vietnamese projects were focused on Costless-Easy and Cost-Easy credits groups. Additionally, several Cost-Hard group credits are popular such as WEc2, EAc1, EAc2, EQc4.3, with the reason being that these credits have a large percentage of points in LEED and most of the LEED projects in Vietnam are LEED silver or gold. A lot of Costless-Hard credits have not been implemented, reflecting the limited experience of LEED consultants in Vietnam. Therefore, some of the credits that are costly but still implemented, such as SSc5.2, SSc7.2, WEc1, WEc3, EQc4.1, EQc4.2, need to be carefully studied and judged before being applied to the projected practice.

**Table 5.** Classification table of costs and difficulty level of LEED credits 2009 by Jae-Yong Park (2017) [12].

Costless-Easy	Costless-Hard	Cost-Easy	Cost-Hard
SSc1 *	SSc3	SSc4.2	SSc6.1
SSc2	SSc7.1 *	SSc5.1	SSc6.2
SSc4.1	SSc8	SSc5.2 *	WEc2 *
SSc4.3 *	EAc4	SSc7.2 *	EAc1 *
SSc4.4 *	MRc1.1	WEc1 *	EAc2 *
MRc2	MRc1.2	WEc3 *	EAc3
MRc4	MRc3	EAc6	EAc5
MRc5 *	EQc2	MRc7	MRc6
EQc7.1	EQc3.1 *	EQc3.2	EQc1
EQc7.2	EQc8.1	EQc4.1 *	EQc4.3 *
	EQc8.2	EQc4.2 *	EQc4.4
		EQc6.1	EQc5
			EQc6.2

\* are the significant popular credits at LEED projects in Vietnam.

In addition, LEED specialists need to study more and understand clearly the costless and uncommon credits group to offer appropriate solutions. For example, SSc2 and SSc4.1 credits relate to community connectivity planning, and it may not be feasible for many projects because of the current urban conditions in Vietnam. The construction waste management, MRc2, is currently only implemented by well-known contractors, so the Vietnamese government should have stricter regulations to promote them. As a result of uncommon materials with sustainability certificates, the credits for materials are not offered in the Vietnamese LEED project. The credits of SSc8, EQc8,

EQc2, EAc4, and SSc3 had not been implemented in many projects, and this predicted that the idea contribution meetings did not work well. Therefore, the roles of LEED experts and the integrative design process need to be addressed in the future.

### 5.2. Converting Results to LEED Version 4

Besides the significant changes, as mentioned in the literature review section, some of the credits are combined or renamed, which included the following changes, such as the SSc7.1 and SSc7.2 credits are combined into SSc5; the EQc4.1, EQc4.2, EQc4.3 credits are grouped into EQc2; and most credits have changed names. Not only changing the names and aggregation of credits, but the content of these credits also had specific changes that the project team needs to refer to before deciding on the selection of sustainable credits for their LEED project in the future. Thus, after comparing and converting common LEED credits of LEED 2009 projects in Vietnam, the list of LEED v4 credits proposed by this study includes:

1. SSc1—Site Selection. (1 point)
2. LTc6—Bicycle facilities. (1 point)
3. SSc3—Open space. (1 point)
4. SSc5—Heat island reduction. (1 point)
5. EQc3—Construction indoor air quality management plan. (1 point)
6. EQc2—Low emitting materials. (2.75 points)
7. INc2—LEED Accredited Professional. (1 point)
8. LTc8—Green vehicles. (3.00 point)
9. LTc7—Reduced parking footprint. (1.95 points)
10. WEc1—Water Efficient Landscaping. (3.51 points)
11. WEc3—Water Use Reduction. (3.76 points)
12. WEc2—Innovative Wastewater Technologies. (1.84 points)
13. EAc2—Optimize energy performance. (10.38 points)
14. MRc3—Building product disclosure and optimization-sourcing of raw materials. (3.62 points)

## 6. Conclusions

The important contribution of LEED in driving green building in Vietnam is evidenced through the increase in the number of recent LEED projects registered in recent years. More studying and a deeper understanding of project objectives are needed for the development of green buildings without much additional cost. Understanding the development characteristics of green buildings in Vietnam is also significant for the Vietnamese government to establish appropriate Green Building guidelines and regulations. Therefore, the main contribution of this study to the investigation of the credits earned by LEED buildings in Vietnam, provide benchmarks for future LEED projects to improve. In summary, the key points are:

- The results of significantly awarded credits at LEED projects in Vietnam are identified and the recommended LEED v4 credits are SSc1—Site Selection; LTc6—Bicycle facilities; SSc3—Open space; SSc5—Heat island reduction; EQc3—Construction indoor air quality management plan; EQc2—Low emitting materials; INc2—LEED Accredited Professional; LTc8—Green vehicles; LTc7—Reduced parking footprint; WEc1—Water Efficient Landscaping; WEc3—Water Use Reduction; WEc2—Innovative Wastewater Technologies; EAc2—Optimize energy performance; and MRc3—Building product disclosure and optimization—sourcing of raw materials.
- The significant different credits between the LEED Silver and the LEED Gold projects are SSc5 (SSc7.2), ECc2 (EQc4.1), EQc3 (EQc5), EQc7 (EQc8.1), and EAc2 (EAc1).
- The significant different credits between the LEED Gold and the LEED Platinum projects are SSc1 (SSc4.2), SSc5 (SSc7.2), EAc2 (EAc1), EAc5 (EAc2), and INc1 (IDc1).

In addition, many limitations of research need to be mentioned. First, the number of LEED certificated projects in Vietnam is minimal, and detailed statistical analyses for each type of credit, or buildings in each region, are also not conducted. Thus, project teams need to have deeply researched similar projects because of the uniqueness of construction works. Research data was also collected from LEED v2009, and further research is needed based on data from new LEED v4 projects when the number of LEED v4 projects in Vietnam is large enough.

**Author Contributions:** Conceptualization draft, D.H.P. and B.K.; writing—original draft preparation, D.H.P.; writing—review and editing, D.H.P., A.C.A and J.L.; supervision, Y.A. and A.C.A. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Acknowledgments:** This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2019R111A1A01063207).

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Credits and Symbols of Credits in LEED 2009 and LEED v4.

LEED 2009			LEED v4		
ID	Description	Max Points	ID	Description	Max Points
<b>Sustainable sites</b>		26	IPc1	Integrative process	1
SSc1	Site selection	1	<b>Location &amp; transportation</b>		32
SSc2	Development density and community connectivity	5	LTc1	LEED for Neighborhood Development location	16
SSc3	Brownfield redevelopment	1	LTc2	Credit Sensitive land protection	1
SSc4.1	Alternative transportation—public transportation access	6	LTc3	Credit High priority site	2
SSc4.2	Alternative transportation—bicycle storage and changing rooms	1	LTc4	Credit Surrounding density and diverse uses	5
SSc4.3	Alternative transportation—low-emitting and fuel-efficient vehicles	3	LTc5	Credit Access to quality transit	5
SSc4.4	Alternative transportation—parking capacity	2	LTc6	Credit Bicycle facilities	1
SSc5.1	Site development—protect or restore habitat	1	LTc7	Credit Reduced parking footprint	1
SSc5.2	Site development—maximize open space	1	LTc8	Credit Green vehicles	1
SSc6.1	Stormwater design—quantity control	1	<b>Sustainable sites</b>		10
SSc6.2	Stormwater design—quality control	1	SSc1	Site assessment	1
SSc7.1	Heat island effect—non-roof	1	SSc2	Site development—protect or restore habitat	2
SSc7.2	Heat island effect—roof	1	SSc3	Open space	1
SSc8	Light pollution reduction	1	SSc4	Rainwater Mgmt	3
<b>Water efficiency</b>		10	SSc5	Heat island reduction	2
WEc1	Water efficient landscaping	4	SSc6	Light pollution reduction	1
WEc2	Innovative wastewater technologies	2	<b>Water efficiency</b>		11
WEc3	Water use reduction	4	Wc1	Cooling tower water use	2

Table A1. Cont.

LEED 2009			LEED v4		
ID	Description	Max Points	ID	Description	Max Points
<b>Energy and atmosphere</b>		35	<b>Wc2</b>	Water metering	1
EAc1	Optimize energy performance	19	<b>Wc3</b>	Outdoor water use reduction	2
EAc2	On-site renewable energy	7	<b>Wc4</b>	Indoor water use reduction	6
EAc3	Enhanced commissioning	2	<b>Energy and atmosphere</b>		<b>33</b>
EAc4	Enhanced refrigerant management	2	EAc1	Enhanced commissioning	6
EAc5	Measurement and verification	3	EAc2	Advanced energy metering	1
EAc6	Green power	2	EAc3	Demand response	2
<b>Material and resources</b>		14	EAc4	Renewable energy production	3
MRc1.1	Building reuse—maintain existing walls, floors and roof	3	EAc5	Enhanced refrigerant Mgmt	1
MRc1.2	Building reuse—maintain interior nonstructural elements	1	EAc6	Green power and carbon offsets	2
MRc2	Construction waste management	2	EAc7	Optimize energy performance	18
MRc3	Materials reuse	2	<b>Material and resources</b>		<b>13</b>
MRc4	Recycled content	2	Mrc1	Building life-cycle impact reduction	5
MRc5	Regional materials	2	Mrc2	Building product disclosure and optimization—environmental product declarations	2
MRc6	Rapidly renewable materials	1	Mrc3	Building product disclosure and optimization—sourcing of raw materials	2
MRc7	Certified wood	1	Mrc4	Building product disclosure and optimization—material ingredients	2
<b>Indoor environmental quality</b>		15	Mrc5	Construction and demolition waste Mgmt	2
EQc1	Outdoor air delivery monitoring	1	<b>Indoor environmental quality</b>		<b>16</b>
EQc2	Increased ventilation	1	IEQc1	Enhanced IAQ strategies	2
EQc3.1	Construction IAQ management plan—during construction	1	IEQc2	Low-emitting materials	3
EQc3.2	Construction IAQ management plan—before occupancy	1	IEQc3	Construction IAQ Mgmt plan	1
EQc4.1	Low-emitting materials—adhesives and sealants	1	IEQc4	IAQ assessment	2
EQc4.2	Low-emitting materials—paints and coatings	1	IEQc5	Thermal comfort	1
EQc4.3	Low-emitting materials—flooring systems	1	IEQc6	Interior lighting	2
EQc4.4	Low-emitting materials—composite wood and agrifiber products	1	IEQc7	Daylight	3
EQc5	Indoor chemical and pollutant source control	1	IEQc8	Quality views	1
EQc6.1	Controllability of systems—lighting	1	IEQc9	Acoustic performance	1
EQc6.2	Controllability of systems—thermal comfort	1	<b>Innovation</b>		<b>6</b>
EQc7.1	Thermal comfort—design	1	INc1	Innovation	5
EQc7.2	Thermal comfort—verification	1	INc2	LEED Accredited Professional	1
EQc8.1	Daylight and views—daylight	1	<b>Regional priority credits</b>		<b>4</b>
EQc8.2	Daylight and views—views	1			
<b>Innovation</b>		8			
IDc1	Innovation in design	3			
IDc2	LEED Accredited Professional	1			
<b>Regional priority credits</b>		4			

## References

1. Nguyen, H.-T.; Skitmore, M.; Gray, M.; Zhang, X.; Olanipekun, A.O.J. Will green building development take off? An exploratory study of barriers to green building in Vietnam. *Resour. Conserv. Recycl.* **2017**, *127*, 8–20. [[CrossRef](#)]
2. Kulp, S.A.; Strauss, B.H.J. New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nat. Commun.* **2019**, *10*, 4844. [[CrossRef](#)] [[PubMed](#)]
3. Pham, D.H.; Lee, J.; Ahn, Y.J. Implementing LEED v4 BD+ C Projects in Vietnam: Contributions and Challenges for General Contractor. *Sustainability* **2019**, *11*, 5449. [[CrossRef](#)]

4. Ahn, Y.H.; Jung, C.W.; Suh, M.; Jeon, M.H.J. Integrated construction process for green building. *Procedia Eng.* **2016**, *145*, 670–676. [[CrossRef](#)]
5. Choi, J.; Bhatla, A.; Stoppel, C.; Shane, J.J.S. LEED credit review system and optimization model for pursuing LEED certification. *Sustainability* **2015**, *7*, 13351–13377. [[CrossRef](#)]
6. Wu, P.; Song, Y.; Shou, W.; Chi, H.; Chong, H.-Y.; Sutrisna, M.J.R. A comprehensive analysis of the credits obtained by LEED 2009 certified green buildings. *Renew. Sustain. Energy Rev.* **2017**, *68*, 370–379. [[CrossRef](#)]
7. Dwaikat, L.N.; Ali, K.N.J. Green buildings cost premium: A review of empirical evidence. *Energy Build.* **2016**, *110*, 396–403. [[CrossRef](#)]
8. U.S. Green Building Council. *LEED v4 for Building Design and Construction*; U.S. Green Building Council: Washington, DC, USA, 2014.
9. Nyikos, D.M.; Thal, A.E.; Hicks, M.J.; Leach, S.E. To LEED or not to LEED: Analysis of cost premiums associated with sustainable facility design. *Eng. Manag. J.* **2012**, *24*, 50–62. [[CrossRef](#)]
10. Morris, P.; Langdon, D.J. What does green really cost. *PREA Q.* **2007**, 55–60.
11. Cheng, J.C.; Ma, L.J. A non-linear case-based reasoning approach for retrieval of similar cases and selection of target credits in LEED projects. *Build. Environ.* **2015**, *93*, 349–361. [[CrossRef](#)]
12. Park, J.-Y.; Choi, S.-G.; Kim, D.-K.; Jeong, M.-C.; Kong, J.-S. Credit optimization algorithm for calculating LEED costs. *Sustainability* **2017**, *9*, 1607. [[CrossRef](#)]
13. Jun, M.; Cheng, J.C. Selection of target LEED credits based on project information and climatic factors using data mining techniques. *Adv. Eng. Inform.* **2017**, *32*, 224–236. [[CrossRef](#)]
14. Ma, J.; Cheng, J.C. Data-driven study on the achievement of LEED credits using percentage of average score and association rule analysis. *Build. Environ.* **2016**, *98*, 121–132. [[CrossRef](#)]
15. Jalaei, F.; Irade, A. Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings. *Sustain. Cities Soc.* **2015**, *18*, 95–107. [[CrossRef](#)]
16. Chen, P.-H.; Nguyen, T.C. Integrating web map service and building information modeling for location and transportation analysis in green building certification process. *Autom. Constr.* **2017**, *77*, 52–66. [[CrossRef](#)]
17. Pushkar, S. Sacrificial Pseudoreplication in LEED Cross-Certification Strategy Assessment: Sampling Structures. *Sustainability* **2018**, *10*, 1353. [[CrossRef](#)]
18. Wu, P.; Song, Y.; Wang, J.; Wang, X.; Zhao, X.; He, Q. Regional variations of credits obtained by LEED 2009 certified green buildings—A country level analysis. *Sustainability* **2018**, *10*, 20. [[CrossRef](#)]
19. Da Silva, L.; Ruwanpura, J.Y. Review of the LEED points obtained by Canadian building projects. *J. Archit. Eng.* **2009**, *15*, 38–54. [[CrossRef](#)]
20. Cidell, J.; Beata, A. Spatial variation among green building certification categories: Does place matter? *Landsc. Urban Plan.* **2009**, *91*, 142–151. [[CrossRef](#)]
21. Madanayake, H.S.P.; Ruwanpura, J.Y. Multi-criteria decision making to improve performance in construction projects with LEED certification. In Proceedings of the Construction Research Congress 2012: Construction Challenges in a Flat World, West Lafayette, IN, USA, 21–23 May 2012; pp. 1899–1909.
22. Juan, Y.-K.; Gao, P.; Wang, J. A hybrid decision support system for sustainable office building renovation and energy performance improvement. *Energy Build.* **2010**, *42*, 290–297. [[CrossRef](#)]
23. Castro-Lacouture, D.; Sefair, J.A.; Flórez, L.; Medaglia, A.L. Optimization model for the selection of materials using a LEED-based green building rating system in Colombia. *Build. Environ.* **2009**, *44*, 1162–1170. [[CrossRef](#)]
24. Zimmerman, A.; Kibert, C.J. Informing LEED's next generation with The Natural Step. *Build. Res. Inf.* **2007**, *35*, 681–689. [[CrossRef](#)]
25. Pushkar, S. A Comparative Analysis of Gold Leadership in Energy and Environmental Design for New Construction 2009 Certified Projects in Finland, Sweden, Turkey, and Spain. *Appl. Sci.* **2018**, *8*, 1496. [[CrossRef](#)]
26. Potbhare, V.; Syal, M.; Arif, M.; Khalfan, M.M.; Egbu, C. Emergence of green building guidelines in developed countries and their impact on India. *J. Eng. Des. Technol.* **2009**, *7*, 99–121. [[CrossRef](#)]
27. Kubba, S. *LEED Practices, Certification, and Accreditation Handbook*; Butterworth-Heinemann: Oxford, UK, 2009.
28. USGBC. *Summary of Changes: LEED 2009 to v4—BD+C*; USGBC: Washington, DC, USA, 2009.
29. Hogg, R.V.; Tanis, E.A.; Zimmerman, D.L. *Probability and Statistical Inference*; Pearson: London, UK, 2015.
30. Tourism, G.D.o. Socialist Republic of Vietnam. Available online: <http://asosai14.vn/80-1/viet-nam-dat-buoc-con-nguoi.sav> (accessed on 20 January 2020).



31. Cliff, N. Dominance statistics: Ordinal analyses to answer ordinal questions. *Psychol. Bull.* **1993**, *114*, 494. [[CrossRef](#)]
32. Marx, A.; Backes, C.; Meese, E.; Lenhof, H.-P.; Keller, A. EDISON-WMW: Exact dynamic programming solution of the Wilcoxon–Mann–Whitney test. *Genom. Proteom. Bioinform.* **2016**, *14*, 55–61. [[CrossRef](#)]



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).