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# Impact of "Optimize Energy Performance" Credit Achievement on the Compensation Strategy of Leadership in Energy and Environmental Design for Existing Buildings Gold-Certified Office Space Projects in Madrid and Barcelona, Spain

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**Abstract:** The Leadership in Energy and Environmental Design for Existing Buildings (LEED-EB) version 3 (v3) and version 4 (v4) gold-certified office space certification strategies in Spain have not yet been studied. The two purposes of this study were to evaluate (1) the impact of high or low achievements in the energy and atmosphere (EA) "optimize energy performance" credit (EAc1 for v3 and EAc8 for v4) on the compensation strategy for LEED "compensation group" credits and (2) the impact of EAc1-v3 or EAc8-v4 on the monotonic change in LEED "compensation group" credits. Data on a total of 77 LEED-EB v3 and 43 LEED-EB v4 gold-certified office space projects were collected. In the v3 group, 26 LEED-certified projects had the highest EAc1 achievements (v3 group 1), and 26 LEED-certified projects had the lowest EAc1 achievements (v3 group 2). In the v4 group, 15 LEED-certified projects had the highest EAc8 achievements (v4 group 1), and 15 LEED-certified projects had the lowest EAc8 achievements (v4 group 2). The exact Wilcoxon–Mann–Whitney test and Fisher's exact $2 \times 2$ with Lancaster's correction test were used to estimate the difference between groups 1 and 2. Spearman's rank-order correlation was used to assess monotonic change in LEED credits. The results show that v3 and v4 group 1 outperformed v3 and v4 group 2 in EAc1 and EAc8 ($p < 0.0001$, respectively). However, v3 and v4 group 2 outperformed v3 and v4 group 1 in "renewable energy" (EAc4 for v3 and EAc6 for v4, $p = 0.0039$ and 0.0088, respectively) and "building commissioning" (EAc2.2 for v3, $p = 0.0015$; EAc3 for v4, $p = 0.0560$, respectively). EAc1-v3 and LEED v3 "compensation group" credits showed a moderate negative correlation ($r_s = -0.53$ and $p < 0.0001$). EAc8-v4 and LEED v4 "compensation group" credits showed a strong negative correlation ($r_s = -0.74$ and $p < 0.0001$). As a result, increasing the share of renewable energy and performing building commissioning in LEED-EB v3- and v4-certified projects occurred only as a compensation strategy in response to the low achievement in the "optimize energy performance" credit.

**Keywords:** LEED-EB v3 and v4; optimize energy performance credit; compensation strategy; Spain; Madrid; Barcelona

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## 1. Introduction

In 2017, Wu et al. [1] noted that Leadership in Energy and Environmental Design (LEED) version 3 (v3) was the most commonly used green building rating system worldwide. However, LEED version 4 (v4) was already being actively used in the USA, China [2], Vietnam [3], Finland, and Spain [4] between 2019 and 2020.

LEED v3 2009 certified projects comprise five main categories, namely sustainable sites (SS), water efficiency (WE), energy and atmosphere (EA), materials and resources (MRs), and indoor and environmental quality (EQ), and two additional categories, namely innovation in design (ID) and regional priority (RP). With the transition of the LEED rating system from v3 to v4, the SS credit "alternative commuting transport" was separated into a single category: "location and transport" (LT). Each category includes the number of qualifying credits. Credits have requirements, and corresponding points are awarded. Depending on the total number of LEED points, four levels of certification can be achieved (certified, silver, gold, and platinum, requiring 40–49, 50–59, 60–79, and 80+ points, respectively).

LEED is a flexible system that allows for a variety of certification strategies. The appropriate certification strategy depends on the specific characteristics of the country in which the LEED-certified building is located. This means that the certification strategy depends on the following factors: the local climate, natural resources, building technologies and materials, green policies and standards, and cultural traditions [5]. In addition, certification strategies in the same country may depend on building factors, such as building type and size. Investigating these factors can help LEED practitioners select the most appropriate certification strategy within the project's budget and schedule constraints [6].

The climate factor was studied in [7], wherein LEED for Existing Building v3 (LEED-EBv3)-certified projects in the US were analyzed. The authors revealed that the daily temperature range factor is highly correlated with the achievements in SSc7.1 "Heat Island Reduction—Non-Roof". Subsequently, a methodology for choosing a certification strategy for the climate factor was presented [8].

The building type factor was studied by Gurgun and Arditi [9]. The authors analyzed the EA credit strategy of silver, gold, and platinum LEED for New Construction v3 (LEED-NCv3) projects in the US. It was concluded that, in buildings constructed for private corporations, educational institutions, publicly traded corporations, government agencies, and investors, EA credits have made various achievements.

Compared to other categories, EA had the highest maximum point value in both v3 and v4. The EA category contains the "optimize energy performance" credit, with a maximum score comprising up to 19% of total LEED credits in v3 and v4. Therefore, changes in this high-score credit achievement will lead to different certification strategies in LEED-certified projects at the same certification level.

Recently, the impact of "optimize energy performance" on the preferred LEED strategy has been studied in different countries. In 2023, Pushkar [10–12] used a range of LEED-certified projects with the highest to lowest achievements in the "optimize energy performance" credit to study different LEED certification strategies. This sorting procedure can be properly applied if the following conditions are met: The number of LEED-certified projects in both groups with the highest and lowest achievements in the "optimize energy performance" credit should not be <12, and the number of LEED-certified projects in the two groups should be approximately the same. In addition, these LEED-certified projects, depending on the context, should belong to either one district in a city, one city, or one country. In this case, all LEED-certified projects must belong to the same sampling frame, with each LEED-certified project as the primary sampling unit [13]. All LEED-certified projects must also be of the same system, same version, and same certification level.

Recently, this methodological approach has been applied in several countries. In Germany [10], LEED-NC v3 gold-certified office space projects were analyzed. In the group with the lowest "optimize energy performance" credit, LEED credits did not demonstrate any significant compensation strategy for achieving the same certification level as the group with the highest achievements in this credit. This discrepancy occurred because the overall LEED score considerably exceeded that required for the minimum gold-level certification in groups 1 and 2 with the highest and lowest achievements in the "optimize energy performance" credit (minimum = 60 points, median and 25th–75th percentiles in groups 1 and 2: 67.0, 64.8–69.3, and 64.0, 62.5–64.3, respectively).

In Shanghai, China [11], LEED for Commercial Interiors v4 (LEED-CI v4) gold-certified office space projects were analyzed. In the group with the lowest "optimize energy performance" credit, the "low-emitting materials" and "quality views" credits from the EQ category demonstrated a compensation strategy that achieved the same certification level as the group with the highest achievements in this credit.

In Manhattan, New York City, USA [12], LEED-CI v4 gold-certified office space projects were analyzed. In the group with the lowest "optimize energy performance" credit, the "interiors life cycle impact reduction" and "building product disclosure and optimization—material ingredients" credits from the MRs category and "low—emitting materials" credit from the EQ category demonstrated a compensation strategy, achieving the same certification level as the group with the highest achievements in this credit.

The three examples above show that the compensation strategies were different in all three studies, indicating that at least two different LEED certification strategies can be used to achieve the same certification level in LEED-certified projects. The first includes high achievements in the "optimize energy performance" credit, and the second includes low achievements in the "optimize energy performance" credit, with a compensating increase in achievements in other LEED credits.

The problem is that the two strategies' environmental impacts may differ despite being applied in one country/city/borough [10–12]. Moreover, these differences in environmental impact are highly dependent on fuel sources for energy production in the country of application. For example, in Shanghai, when using fossil fuels for energy production, the highest achievement strategy in the "optimize energy performance" credit showed less environmental impact than the lowest achievement strategy in the "optimize energy performance" credit. However, when using renewable fuels for energy production, no difference was found between the two strategies with the highest and lowest achievements in the "optimize energy performance" credit [11].

Building contractors must understand which of the above scenarios is more environmentally friendly in order to choose a preferable LEED certification strategy. Research for this study is ongoing with respect to the certification strategies applied in Spain, one of the European countries where LEED certification is popular [14]. In this country, energy is produced using about 40% renewable sources, 40% fossil fuels, and 20% nuclear energy. The current share of renewable energy sources should increase to approximately 90% by 2030 [15].

In 2020, the author of this study [4] compared the differences between Finland and Spain in terms of LEED-EB gold-certified office space projects under transition from v3 to v4. However, Pushkar's study had at least two limitations: (1) differences in the transition from v3 to v4 were assessed between Finland and Spain rather than within each country, and (2) the ranking of LEED-certified projects by high and low achievements in the "optimize energy performance" credit was not performed due to a small sample size. In the study [4], the total sample size (N) was N = 16 in both v3 and v4 of the LEED-EB gold-certified projects. With the current study design, the sample size for groups 1 and 2 would be $n_1 = n_2 = 6$. However, with these sample sizes, significant differences between groups 1 and 2 only occur for very large effect sizes. This effect size is extremely rare in LEED studies [10–12]. Addressing the small sample size problem by pooling LEED-certified projects from different countries may obscure the actual LEED certification strategies for each country individually. Thus, LEED-EB v3 and v4 certification strategies in Spain have not been sufficiently explored.

The purpose of this study was to examine the impact of "optimize energy performance" credit achievements on the compensation strategies of office space projects in Spain for obtaining LEED-EB-v3 and v4 gold certification.

The novelty and contribution of this study are that, for the first time, two LEED certification strategies were identified through an analysis of LEED-EB v3 and v4 gold-certified space office projects in Madrid and Barcelona, Spain. As a result, it was established that increasing the share of renewable energy sources and monitoring energy system efficiency in LEED-EB-certified projects occur only as a compensatory strategy in response to low achievements in the energy-saving credit.

## 2. Materials and Methods

### 2.1. Flow of Statistical Methods in Infographics

Table 1 shows two types of statistical analyses. The type of statistical analysis located on the left side of Table 1 is used to handle dichotomous LEED data. The type of statistical analysis located on the right side of Table 1 is used to process ordinal and discrete data.

**Table 1.** Flow of statistical methods in infographics.

| LEED Data Treatment According to the Type of Measurement Scale | |
|---|---|
| The dichotomous (nominal) scale | The ordinal and discrete (interval) scales |
| The Fisher's exact 2 × 2 contingency table procedure | The Wilcoxon–Wilcoxon–Mann–Whitney test |
| The natural logarithm of the odds ratio ($ln\theta$) | Cliff's $\delta$ test |
| | Spearman's rank correlation coefficient |

Equation (1) shows Fisher's exact 2 × 2 contingency table procedure:

$$P_{Fisher} = \frac{(a+b)!(c+d)!(a+c)!(b+d)!}{N!a!b!c!d!} \tag{1}$$

were variables "*a*" and "*b*" and variables "*c*" and "*d*" indicate the frequency of LEED credit use in the high and low achievement in the "optimize energy performance" credit, respectively.

Equation (2) shows the procedure for the Wilcoxon–Wilcoxon–Mann–Whitney test:

$$W = \sum_{i=1}^{n_A} R_i \tag{2}$$

where $W$ represents the sum of the ranks in the $A$ sample as the test statistic (Wilcoxon rank sum statistic), and $R_i$ represents the sum of the ranks in the pooled sample of all $n = n_A + n_B$ observations.

Equation (3) shows the procedure for the natural logarithm of the odds ratio (ln$\theta$):

$$\ln\theta = \ln\left(\frac{(a \times d)}{(c \times b)}\right) \tag{3}$$

were variables "*a*" and "*b*" and variables "*c*" and "*d*" indicate the frequency of LEED credit use in the high and low achievement in the "optimize energy performance" credit, respectively.

Equation (4) shows the procedure for Cliff's $\delta$ test:

$$\delta = \#(x_1 > x_2) - \#(x_1 < x_2)/(n_1 n_2) \tag{4}$$

where $x_1$ and $x_2$ are scores within group 1 and group 2, respectively; $n_1$ and $n_2$ are the sizes of the sample groups, group 1 and group 2; and # indicates the number of times.

Equation (5) shows the procedure for Spearman's rank correlation coefficient:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \tag{5}$$

### *2.2. Design of the Study*

Regarding the statistical analysis of LEED-certified projects, the study design should contain the following assumptions: LEED data should be collected from one region, using the same rating system, version, certification level, and type of space, with a suitable sample size. Such assumptions were applied to maximally reduce nondemonic intrusion, defined as "the impingement of chance events on an experiment in progress" [16]. Recently, the same study design was used to analyze LEED-certified projects in Germany [10].

#### 2.2.1. Data Collection

The US Green Building Council and Green Building Information Gateway databases were used to collect data on 77 LEED-EB v3 and 43 LEED-EB v4 gold-certified office space projects in Spain [17,18]. For both v3 and 4 projects, LEED-EB projects were ranked from the highest to the lowest achievements in the "optimize energy performance" credit (EAc1 for v3 and EAc8 for v4).

#### 2.2.2. Data Sorted into Two Groups

For v3, the 26 LEED-certified projects with the highest EAc1 were identified as group 1 (v3), and the 26 LEED-certified projects with the lowest EAc1 were identified as group 2 (v3). For v4, the 15 LEED-certified projects with the highest EAc8 were identified as group 1 (v4), and the 15 LEED-certified projects with the lowest EAc8 projects were identified as group 2 (v4). In terms of the statistical analysis, the LEED-certified projects were identified as the sample size ($n$) of the independent primary sampling units, where one sampling frame (i.e., v3) contained two independent groups, and another sampling frame (i.e., v4) contained two independent groups [13]. Therefore, groups 1 and 2 from the LEED v3 projects were identified as $n_1 = n_2 = 26$, and groups 1 and 2 from the LEED v4 projects were identified as $n_1 = n_2 = 15$.

#### 2.2.3. Data Sorted into One Group

All 77 LEED-EB v3 gold-certified projects were sorted into one group. All 43 LEED-EB v4 gold-certified projects were sorted into another group. This design was used to investigate the monotonic negative correlation between the decrease in achievements in the "optimize energy performance" credit and the increase in achievements in LEED credits to reach the gold certification level in LEED-certified projects.

### *2.3. Statistical Analysis*

#### 2.3.1. Descriptive and Inferential Statistics

In the present study, the author used non-parametric statistics instead of parametric statistics because the assumption of normality was not met [12]. For descriptive statistics, the author used the median and 25–75th percentiles instead of the mean and standard deviation. For inferential statistics, the author used nonparametric effect size and significance tests. When the LEED data were on an ordinal or a discrete (interval) scale, the author used Cliff's effect size $\delta$ test [19] and the exact Wilcoxon–Mann–Whitney (WMW) test [20]. When the LEED data were on a dichotomous (nominal) scale, the author used the natural logarithm of the odds ratio ($ln\theta$) effect size test [21] and Fisher's exact test, using a $2 \times 2$ table with Lancaster's correction [22].

#### 2.3.2. Limitation of Sample Size

If it is necessary to obtain $p < 0.05$ using significance tests, then the sample size is a real concern [23]. If the exact WMW test is used, then the minimum sample size ($n$) is $n_1 = n_2 = 4$ [24]. If Fisher's exact $2 \times 2$ table test with Lancaster's correction is used, then the minimum sample size ($n$) is $n_1 = n_2 = 3$ [22]. In the present study, the author used two sets of sample sizes: $n_1 = n_2 = 26$ and $n_1 = n_2 = 15$. Thus, the current sample sizes can provide reliable statistical inference.

#### 2.3.3. Effect Size Interpretation

In the context of the effect size interpretation, group 1 included LEED-certified projects with the highest achievement in the "optimize energy performance" credit, while group 2 included LEED-certified projects with the lowest achievement in the "optimize energy performance" credit.

Cliff's $\delta$ ranges between $-1$ and +1, and $ln\theta$ ranges from minus infinity to plus infinity. In both $\delta$ and $ln\theta$, (+) indicates that group 1 is superior to group 2, (–) indicates that group 2 is superior to group 1, and zero indicates no difference between the groups. For the $ln\theta$ test, the Fleiss procedure (adding 0.5 to each observed frequency) was used if one of the proportions in the fourfold table was zero [25].

Table 2 shows the absolute effect size thresholds (negligible, small, medium, and large) for Cliff's $\delta$ and $|ln\theta|$.

**Table 2.** The absolute effect size thresholds.

| Effect Size Estimation Procedure | Negligible | Small | Medium | Large | Reference |
|---|---|---|---|---|---|
| Absolute Cliff's $\delta$ $\lvert\delta\rvert$ | <0.147 | 0.147 | 0.33 | 0.474 | [26] |
| Absolute natural log odds ratio $\lvert ln\theta \rvert$ | <0.51 | 0.51 | 1.24 | 1.90 | [27] |

According to Cohen [28], a medium effect is visible to the naked eye of a careful observer. A low effect is noticeably smaller than medium but not so small as to be trivial. A high effect is the same distance above the medium effect as the distance to which the small effect is below it.

#### 2.3.4. Spearman's Rank Correlation Test Interpretation

The author collected data on 77 LEED-EB v3 and 43 LEED-EB v4 gold-certified projects in Spain. According to Mundry and Fisher [29], the minimal sample size for Spearman's rank-order correlation test is 25. Thus, the number of LEED-certified projects in both v3 and v4 allows this test to be used to produce a powerful statistical inference. In the present study, the results of Spearman's rank-order correlation test are shown in a tabular form instead of a graphical one because the LEED data contain a certain amount of tied data, which distorts the visual assessment of the figure.

The value of Spearman's rank correlation coefficient ($r_s$) $r_s$ ranges between −1 and +1. A positive value (+) indicates a monotonic increase in two independent variables. A negative value (−) indicates a monotonic increase in one independent variable and a monotonic decrease in the other independent variable. A value of zero indicates no relationship between the two independent variables. Table 3 illustrates the absolute strength of the association $\lvert r_s \rvert$ that was used to interpret the relationship between two independent variables.

**Table 3.** Interpretation of the correlation coefficient in absolute values.

| Coefficient | Very Weak | Weak | Moderate | Strong | Very Strong | Reference |
|---|---|---|---|---|---|---|
| $\lvert r_s \rvert$ | 0.00–0.19 | 0.20–0.39 | 0.40–0.59 | 0.60–0.79 | 0.80–1.00 | [30] |

The correlation coefficient $\lvert r_s \rvert$ was used to calculate the *p*-value using the *t* distribution.

#### 2.3.5. *p*-Value Interpretation

Traditionally, in inferential statistics, the *p*-value is interpreted using the Paleo–Fisherian and Neyman–Pearson paradigms according to $\alpha$ as the fixed value, i.e., by using the level of significance (e.g., $\alpha$ = 0.05) and dichotomizing the scale of the *p*-values, i.e., $p \leq \alpha$ or $p > \alpha$ [31]. A comprehensive study [31] showed that the fixation condition $\alpha$ is redundant. Hurlbert and Lombardi [31] cited Fischer's logical note that "no scientific worker has a fixed level of significance at which from year to year, and in all circumstances, he rejects [null] hypotheses; he rather gives his mind to each particular case in light of his evidence and ideas" [32]. Thus, both the exact *p*-value and effect size were used to interpret statistical inferences (with no need to report $\alpha$). Hurlbert and Lombardi [31] cited the recommendation of Gotelli and Ellison [33], noting that, "in many cases, it may be more important to report the exact p-value and let the readers decide for themselves how important the results are". According to an analysis of data from LEED-certified projects [34], a significant difference between two unpaired groups with a sample size of about $n_1 = n_2 = 20$ can occur with a combination of a medium or large effect size and a low *p*-value.

## 3. Results and Discussion

### *3.1. Analysis of Project Distribution*

Table 4 shows the distribution and distribution percentage (%) of LEED-EB v3 and v4 gold-certified office space projects in Spanish cities. In v3, most group 1 and 2 projects were located in Madrid, with high and low achievements, respectively, in the "optimize energy performance" credit. In v4, most projects belonging to group 1 were located in Madrid, and almost an equal number of projects belonging to group 2 were located in both Madrid and Barcelona.

**Table 4.** Distribution and distribution percentage (%) of LEED-EB v3 and v4 gold-certified office space projects in Spanish cities: group 1, group 2, and intermediate group.

| LEED-EB Version | Number of Projects | | | |
|---|---|---|---|---|
| | Group 1 ("Optimize Energy Performance" Credit High-Achievement Strategy) | | Group 2 ("Optimize Energy Performance" Credit Low-Achievement Strategy) | |
| | Madrid | Barcelona | Madrid | Barcelona |
| v3 | 24 (92) | 2 (8) | 21(81) | 5 (19) |
| v4 | 13 (87) | 2 (13) | 7 (47) | 8 (53) |
| | Intermediate group ("optimize energy performance" credit intermediate-achievement strategy between groups 1 and 2) | | | |
| | Madrid | Barcelona | Other cities | |
| v3 | 12 (48) | 3 (12) | 10 (40) | |
| v4 | 5 (38) | 7 (54) | 1 (8) | |

It should be noted that groups 1 and 2 included only two cities, Madrid and Barcelona, in both v3 and v4, whereas in the intermediate group, in addition to Madrid and Barcelona, other Spanish cities were included. The author examined the differences between extreme groups 1 and 2 in the present study.

These two extreme groups are of special interest because the analyzed projects were located in two cities, Madrid and Barcelona. According to Zarco-Soto et al. [35], both cities have >1 million inhabitants (Madrid, >3 million; Barcelona, >1.5 million). Madrid has a continental climate, whereas Barcelona has a Mediterranean climate. The continental climate is characterized by extreme temperatures in winter and summer, whereas the Mediterranean climate has mild winters and warm summers. Thus, operating energy consumption for the heating and cooling of buildings is significant in both climates. However, in the continental climate, it is higher than in the Mediterranean climate [35].

Therefore, it can be supposed that, in Madrid, energy saving is a more important issue than in Barcelona. This assumption is contradictory to the v3 results presented in Table 4, in which most projects in both groups 1 (high energy saving) and 2 (low energy saving) were located in Madrid. However, the assumption is confirmed by the v4 results presented in Table 4, in which most projects in group 1 (high energy saving) were located in Madrid, whereas an almost equal number of projects in group 2 (low energy saving) were located in both Madrid and Barcelona.

### 3.2. Category Analysis

Table 5 shows the certification strategies for LEED-EB v3 and v4 gold-certified office space projects in groups 1 and 2. No significant difference was found between groups 1 and 2 in terms of the total LEED score in both v3- and v4-certified projects ($p$ = 0.2486 and 0.4769, respectively). However, groups 1 and 2 used different certification strategies to obtain gold certification. For the v3 and v4 certification strategies, group 1 outperformed group 2 in the EA category ($p \leq 0.0084$).

**Table 5.** LEED-EB v3 and v4 gold-certified office space projects at the category level in Spain: group 1 versus group 2.

| Category | Maximum Points | Median, 25–75th Percentiles | | Cliff's $\delta$ | $p$-Value |
|---|---|---|---|---|---|
| | | Group 1 | Group 2 | | |
| LEED-EB v3 ($n_1$ = $n_2$ = 26) | | | | | |
| Energy and atmosphere (EA) | 35 | 23.0 21.0–26.0 | 21.0 19.0–23.0 | 0.42 | 0.0084 |
| Sustainable sites (SS) | 26 | 18.0 15.0–19.0 | 16.0 12.0–18.0 | 0.29 | 0.0747 |
| Water efficiency (WE) | 14 | 7.0 7.0–9.0 | 7.5 7.0–9.0 | −0.18 | 0.2483 |
| Materials and resources (MRs) | 10 | 2.0 2.0–3.0 | 3.0 2.0–5.0 | −0.37 | 0.0186 |
| Indoor environmental quality (EQ) | 15 | 5.0 4.0–7.0 | 6.5 4.0–8.0 | −0.13 | 0.4387 |
| Innovation (IN) | 6 | 4.0 4.0–5.0 | 4.5 4.0–5.0 | −0.09 | 0.5193 |
| Regional priority (RP) | 4 | 3.5 3.0–4.0 | 4.0 3.0–4.0 | −0.27 | 0.0586 |
| LEED total | 110 | 64.0 62.0–65.0 | 62.0 61.0–65.0 | 0.19 | 0.2486 |
| LEED-EB v4 ($n_1$ = $n_2$ = 15) | | | | | |
| Energy and atmosphere (EA) | 38 | 24.0 24.0–24.0 | 19.0 16.3–20.8 | 0.93 | <0.0001 |
| Location and transportation (LT) | 15 | 15.0 15.0–15.0 | 15.0 14.0–15.0 | 0.29 | 0.1034 |
| Sustainable sites (SS) | 10 | 3.0 2.0–4.5 | 4.0 3.0–5.0 | −0.29 | 0.1701 |
| Water efficiency (WE) | 12 | 6.0 6.0–8.0 | 7.0 7.0–8.8 | −0.30 | 0.1537 |
| Materials and resources (MRs) | 8 | 2.0 1.0–3.0 | 4.0 2.0–4.0 | −0.41 | 0.0515 |
| Indoor environmental quality (EQ) | 17 | 8.0 7.0–9.0 | 9.0 8.0–10.0 | −0.40 | 0.0615 |
| Innovation (IN) | 6 | 4.0 3.0–4.0 | 5.0 4.0–5.0 | −0.68 | 0.0006 |
| Regional priority (RP) | 4 | 4.0 3.0–4.0 | 4.0 3.0–4.0 | 0.07 | 0.7104 |
| LEED total | 110 | 65.0 63.0–67.0 | 64.0 62.3–66.0 | 0.16 | 0.4769 |

To reach the same certification level, group 2 outperformed group 1 in the MRs category for v3 ($p \leq 0.0186$) and in the MRs, EQ, and IN categories for v4 ($p \leq 0.0615$). Thus, it can be assumed that group 2′s compensation strategy aimed to increase achievement in MRs credits for v3, as well as in MRs and EQ credits for v4.

Section 3.3 analyzes credit level to understand the compensation strategy used by group 2. Therefore, the following conditions must be met: group 1 outperforms group 2 in the "optimize energy performance" credit achievement, and group 2 outperforms group 1 in the "compensatory group" of LEED credit achievements. As a result, LEED credits with similar, i.e., high or low achievements in groups 1 and 2 were outside the scope of this study.

### *3.3. Credit Analysis*

Table 6 shows the credits for different achievements in groups 1 and 2. Group 1 outperformed group 2 in "optimize energy performance" (Eac1 for v3 and Eac8 for v4, $p < 0.0001$ in both v3 and v4). In parallel, group 2 outperformed group 1 in "renewable energy" (Eac4 for v3, $p = 0.0039$; Eac6 for v4, $p = 0.0088$) and "building commissioning" (Eac2.2 for v3, $p = 0.0015$; Eac3 for v4, $p = 0.0560$). Thus, the main credits in the compensation strategy of group 2 were the "renewable energy" and "building commissioning" credits.

This compensation strategy was shown in Spain for LEED-EB gold-certified office space projects, but it was not shown in Germany for LEED-NC gold-certified office space projects. For example, in Germany, group 1 outperformed group 2 in the "optimize energy performance" credit ($p < 0.0001$), while group 2 did not outperform group 1 in the "renewable energy" and "enhanced commissioning" credits ($p = 0.2200$ and 0.5712, respectively) [10]. Perhaps one reason for this difference is the difference between the LEED rating systems. In Spain, it is LEED-EB, and, in Germany, it is LEED-NC.

Table 6 shows that, for v3-certified projects, group 1 achieved 18 points and group 2 achieved 13 points for Eac1, saving 45 and 35% above the national median, respectively. For v4-certified projects, group 1 achieved 20 points and group 2 achieved 13 points for Eac8, saving 45 and 38% above the national median, respectively [36,37]. Gómez-Calvet and Martínez-Duart [15] reported that, in 2017, about 40% of energy produced in Spain came from renewable sources, such as hydroelectricity (8%), wind (19%), solar energy (6%), waste (2%), and other renewable energy sources (2%), and about 40% was produced from fossil sources, such as coal (13%) and gas (28%). The remaining energy was produced from nuclear energy (22%).

**Table 6.** Credits in LEED-EB v3 and v4 gold-certified office space projects in Spain: group 1 versus group 2.

| Credit | Maximum Points | Median, 25–75th Percentiles | | Cliff's $\delta$/ln$\theta$ | $p$-Value |
|---|---|---|---|---|---|
| | | Group 1 | Group 2 | | |
| LEED-EB v3 ($n_1$ = $n_2$ = 26) | | | | | |
| Eac1, optimize energy performance [a] | 18 | 18.0 18.0–18.0 | 13.0 11.0–13.0 | 1.00 | <0.0001 |
| Eac2.2, existing building commissioning—implementation [b] | 2 | 0.0 0.0–0.0 | 2.0 0.0–2.0 | −2.01 | 0.0015 |
| Eac4, on-site and off-site renewable energy [a] | 6 | 1.0 0.0–3.0 | 5.0 2.0–6.0 | −0.45 | 0.0039 |
| SSc4, alternative commuting transportation [a] | 15 | 14.0 13.0–15.0 | 12.0 8.0–15.0 | 0.34 | 0.0329 |
| MRc1, sustainable purchasing—ongoing consumables [b] | 1 | 0.0 0.0–0.0 | 0.0 0.0–0.0 | −2.82 | 0.0057 |
| MRc2.1, sustainable purchasing—electric-powered equipment [b] | 1 | 0.0 0.0–0.0 | 0.0 0.0–1.0 | −2.17 | 0.0028 |
| MRc2.2, sustainable purchasing—furniture [b] | 1 | 0.0 0.0–0.0 | 0.0 0.0–0.0 | −2.61 | 0.0127 |
| MRc7, solid waste management—ongoing consumables [b] | 1 | 0.0 0.0–0.0 | 0.0 0.0–1.0 | −1.57 | 0.0196 |
| Eqc2.1, occupant comfort—occupant survey [b] | 1 | 0.0 0.0–0.0 | 0.5 0.0–1.0 | −1.70 | 0.0061 |
| LEED-EB v4 ($n_1$ = $n_2$ = 15) | | | | | |
| Eac3, ongoing commissioning [b] | 3 | 0.0 0.0–0.0 | 0.0 0.0–0.0 | −2.16 | 0.0560 |
| Eac6, renewable energy and carbon offsets [a] | 5 | 0.0 0.0–0.0 | 3.0 0.0–4.0 | −0.49 | 0.0088 |
| Eac8, optimize energy performance [a] | 20 | 20.0 20.0–20.0 | 13.0 11.3–14.0 | 1.00 | <0.0001 |
| SSc1, site development—protect or restore habitat [a] | 2 | 0.0 0.0–0.0 | 1.0 0.0–1.0 | −0.44 | 0.0206 |
| SSc2, rainwater management [b] | 3 | 0.0 0.0–2.3 | 0.0 0.0–0.0 | 2.50 | 0.0249 |
| SSc5, site management [b] | 1 | 0.0 0.0–0.0 | 1.0 1.0–1.0 | −2.77 | 0.0008 |
| SSc6, site improvement plan [b] | 1 | 0.0 0.0–0.0 | 0.0 0.0–1.0 | −2.51 | 0.0269 |
| Eqc2, enhanced indoor air quality strategies [a] | 2 | 1.0 0.0–1.0 | 1.0 1.0–2.0 | −0.40 | 0.0607 |
| Eqc8, green cleaning—equipment [b] | 1 | 0.0 0.0–0.8 | 1.0 0.0–1.0 | −1.42 | 0.0539 |
| Eqc10, occupant comfort survey [b] | 1 | 0.0 0.0–0.0 | 1.0 0.0–1.0 | −2.28 | 0.0161 |

Notes: [a] Cliff's $\delta$ and the exact Wilcoxon–Mann–Whitney test were used to estimate the differences between groups 1 and 2. [b] The natural logarithm of the odds ratio (ln$\theta$) and Fisher's exact test 2 × 2 table were used to estimate the differences between groups 1 and 2.

The first compensation credit of group 2 was the "renewable energy" credit. Table 6 shows that, for v3-certified projects, group 1 achieved one point and group 2 achieved five points for Eac4, corresponding to 3 and 9% of on-site renewable energy usage, respectively. For v4-certified projects, group 1 achieved zero points and group 2 achieved three points for Eac6, corresponding to 0 and 4.5% of on-site renewable energy usage, respectively [36,37]. Thus, owing to the availability of renewables, group 2 compensated for their relatively low energy savings (Eac1 for v3 and Eac8 for v4) with high achievements in renewable energy credits (Eac4 for v3 and Eac6 for v4).

The next compensation credit in group 2 was the "building commissioning" credit. Table 6 shows that, for v3-certified projects, group 1 achieved zero points and group 2 achieved two points for Eac2.2. For v4-certified projects, group 1 achieved zero points and group 2 achieved zero points for Eac3. Thus, by implementing low-cost operational improvements to "optimize energy performance", group 2 compensated for their relatively low energy savings (Eac1 for v3 and Eac8 for v4) with high achievements in "building commissioning" credits (Eac2.2 for v3 and Eac3 for v4).

In addition, several credits from other categories were also included in the compensation strategy of group 2. For v3, these were "sustainable purchasing—ongoing consumables" (MRc1), "sustainable purchasing—electric-powered equipment" (MRc2.1), "sustainable purchasing—furniture" (MRc2.2), "solid waste management—ongoing consumables" (MRc7), and "occupant comfort—occupant survey" (Eqc2.1) ($p \leq 0.0196$) (Table 6). For use in building operations and maintenance, MRc1, MRc2.1, MRc2.2, and MRc7 credits require the purchase of reusable and renewable paper, batteries, desk accessories, computers, monitors, printers, scanners, and furniture [36]. Reused and renewable materials are not attractive to building contractors due to concerns about their quality [38]. However, the need to compensate for poor performance in the "optimize energy performance" (Eac1) credit forced group 2 to include these credits in its compensatory certification strategy. The additional compensatory credit was Eqc2.1. This credit requires the evaluation of the thermal and acoustic comfort of building occupants, indoor air quality, light levels, and other comfort issues [36]. This credit provides important feedback from building occupants and was included in group 2's compensatory certification strategy.

For v4, the compensatory credits were "site development—protect or restore habitat" (SSc1), "rainwater management" (SSc2), "site management" (SSc5), "site improvement plan" (SSc6), "enhanced indoor air quality strategies" (Eqc2), "green cleaning—equipment" (Eqc8), and "occupant comfort survey" (Eqc10) ($p \leq 0.0733$) (Table 6). SSc1, SSc2, SSc5, and SSc6 are credits required to ensure the restoration of damaged areas, a reduced volumetric flow rate through permeable surfaces, a clean and safe building appearance, and a five-year site improvement plan, respectively [37]. The following compensatory credits, Eqc2 and Eqc8, are credits related to improving indoor air quality and environmentally preferable cleaning equipment, respectively [37]. These credits help improve employee well-being; therefore, they were included in group 2's compensation strategy. The last compensatory credit is Eqc10. The requirements for this credit are identical to those for Eqc2.1 (v3) and address feedback from building occupants regarding their thermal and acoustic comfort, indoor air quality, lighting, and cleanliness of the building [37].

### 3.4. Analysis of Spearman's Correlation

Table 7 shows the correlation between LEED v3 Eac1 and other LEED v3 credits, and between LEED v4 Eac8 and other LEED v4 credits that were used in the compensation strategy by office space projects in Spain to obtain LEED v3 and v4 gold certification.

**Table 7.** LEED-EB v3 and LEED-EB v4: correlation between the "optimize energy performance" EAc1 and EAc8 credits and selected compensating LEED credits.

| Variables | $r_s$ | $p$ |
|---|---|---|
| LEED-EB v3 | | |
| EAc1 vs. sum of EAc2.2, EAc4, MRc1, MRc2.1, MRc2.2, and MRc7 | −0.53 | <0.0001 |
| LEED-EB v4 | | |
| EAc8 vs. sum of EAc6, EAc3, SSc1, SSc5, SSc6, EQc2, EQc8, and EQc10 | −0.74 | <0.0001 |

Notes: LEED-EB v3: EAc1, optimize energy performance; EAc2.2, existing building commissioning—implementation; EAc4, on-site and off-site renewable energy; MRc1, sustainable purchasing—ongoing consumables; MRc2.1, sustainable purchasing—electric-powered equipment; MRc2.2, sustainable purchasing—furniture; MRc7, solid waste management—ongoing consumables. LEED-EB v4: EAc3, ongoing commissioning; EAc6, renewable energy and carbon offsets; EAc8, optimize energy performance; SSc1, site development—protect or restore habitat; SSc5, site management; SSc6, site improvement plan; EQc2, enhanced indoor air quality strategies; EQc8, green cleaning—equipment; EQc10, occupant comfort survey.

The relationship between EAc1 and the sum of two EA and four MRs credits showed a significant correlation, with the association having a moderate negative strength ($p < 0.0001$ and $r_s = -0.53$). The inclusion of the EQc2.1 credit in the group of "compensatory" LEED credits did not affect the strength of the association between EAc1 and other LEED credits.

The relationship between EAc8 and the sum of three SS credits and the sum of three EQ credits showed a significant correlation, with the association having a strong negative strength ($p < 0.0001$ and $r_s = -0.74$). The inclusion of the LT category in the "compensation group" of LEED credits did not affect the strength of the association between EAc8 and the "compensatory group" of LEED credits.

A comparison between v3 and v4 LEED gold-certified office space projects in Spain showed two substantial differences between the two versions, v3 and v4, of LEED-EB gold-certified office space projects. The first difference was noted when comparing the "optimize energy performance" credit and the sum of all "compensatory" credits; for v3, a moderate negative correlation was shown, while v4 showed a strong negative correlation. The second difference relates to differences in the composition of the LEED credits in the "compensation group". In v3, the "compensation group" includes two EA credits and four MRs credits, while, in v4, the "compensation group" includes two EA credits, three SS credits, and three EQ credits.

## 4. Conclusions

This study assessed the certification strategies of LEED-EB v3 and v4 gold-certified office space projects in Madrid and Barcelona, Spain. The following was concluded:

- LEED-EB v3 and v4 gold-certified office space projects have at least two certification strategies: (1) high achievements in "optimize energy performance" (EAc1 and EAc8 for v3 and v4, respectively) and low achievements in "renewable energy" (EAc4 and EAc6 for v3 and v4, respectively) and "building commissioning" (EAc2.2 and EAc6 for v3 and v4, respectively) and (2) vice versa. Thus, increasing the share of renewable energy sources and performing building commissioning regarding energy system efficiency in LEED-EB-certified projects occur only as a compensation strategy in response to a low achievement in the "optimize energy performance" credit.
- In LEED-EB v3 gold-certified office space projects, the relationship between the "optimize energy performance" credit and the "compensation group" of LEED credits showed a moderate negative correlation, while in LEED v4 gold-certified office space projects, the relationship between the "optimize energy performance" credit and the "compensation group" of LEED credits showed a strong negative correlation. Thus, the increase in the strength of the association between LEED credits may indicate that version 4, compared to version 3, represents an improved, more flexible green rating system.

The two different identified certification strategies can serve as guides for building practitioners in Madrid and Barcelona, Spain. Given the short time frame for developing strategies and financial constraints, LEED-EB certification strategies can be used to certify existing buildings in Spain.

## 5. Future Directions

According to Bzdok et al. [39], "statistics draws population inferences from a sample and machine learning finds generalizable predictive patterns". Bzdok et al. [39] classified datasets into two types: (1) "long data", where the number of subjects is greater than that of input variables, and (2) "wide data", where the number of input variables exceeds the number of subjects. As a result, the first type should preferably be treated using significance tests, and the second type should preferably be treated using machine learning methods [39]. It should be noted that the dataset in the present study comprises "long data" and not "wide data". However, as the number of input variables increases, the uses of both statistical inference and machine learning can complement each other and provide meaningful findings.

Recently, for LEED-certified buildings, Alshboul et al. [40] used machine learning methods incorporating five key aspects of green building cost, twenty-two sub-features, and a variety of possible green building options to predict optimal green building costs. Alshboul et al. [41] also compared three machine learning-based algorithms, namely, extreme gradient boosting, deep neural network, and random forest algorithms, to predict LEED-certified building costs. They found that the extreme gradient boosting algorithm is more efficient than the other two algorithms. In future studies, machine learning methods should be included to predict LEED certification strategies.

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