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Assessing the Consistency Between the Expected and Actual Influence of LEED-NC Credit Categories on the Sustainability Score

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This study investigates the relationship between the LEED BD+C for New Construction (LEED-NC) scores achieved by projects and their scores from each credit category to assess the consistency between the expected and the actual influence of these credit categories in determining the sustainability of a project. The data was collected about all of the built LEED-BD+C for New Construction projects and the relationships between each credit category and the sustainability level of the projects, defined by LEED scores, were evaluated through multiple linear regression analysis. The findings showed the harmony between the expected and the actual influence of the Energy and Atmosphere category and Sustainable Site category in determining the overall sustainability of the projects. However, the three credit categories of Materials and Resources, Indoor Environmental Quality, and Water Efficiency did not show any harmony between the expected and the actual influence on determining the overall sustainability level of projects. The findings of this study illustrate the need for enhancing the consistency between the existing sustainability evaluation criteria and suggests more comprehensive research on the factors defining the level of sustainability of a project.

Key Words: LEED, Sustainable Site, Energy and Atmosphere, Water Efficiency, Indoor Environmental Quality, Materials and Resources

Introduction

Green building certification systems are developed to enhance the sustainability and efficiency of construction projects. Some factors such as environmental performance, occupant comfort, and human health, which are known as the ultimate goals of any sustainability standard are evaluated through these certification systems. The systems evaluate several aspects of the building life cycle, including design, construction, maintenance, disassembly, energy, raw materials, and pollutant emissions (Kim et al., 2020). Several frameworks and certification systems have been developed to

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evaluate a building's environmental performance and incorporate sustainable development into the design and construction processes (Ali & Al Nsairat, 2009). One of the most commonly used systems to assess the sustainability of buildings and communities is the Leadership in Energy and Environmental Design (LEED) (Wu et al., 2016). Other than defining a set of criteria for evaluating the performance of buildings, this system has the additional benefit of raising public awareness of environmental preservation, fostering the development of green technologies, boosting green technology research and development, and stimulating green building construction (Kim et al., 2020).

Overview of LEED-NC

In 1998, the USGBC has used LEED standards to evaluate buildings based on their environmental performance. Since then, LEED systems have been updated in light of technological advancements and changes in regulations and policies. The most current version of LEED is version 4.1, which has updated some of the credits of LEED version 4. LEED version 4 was developed in 2013 and significantly changed the number of green building systems. Before version 4, LEED v2009 also known as LEED v3 was the common LEED system. In LEED versions 3 and 4, the projects can gain a total of 110 points based on their compliance with the LEED standards. In this system, if a project gains at least 40 points, it is considered a LEED-Certified project. The next level is the LEED-Silver level, which requires between 50-60 points. LEED Gold is achieved if a project receives between 60-80 points, and, as the highest level of LEED certification, LEED-Platinum is achieved if a project receives at least 809 points (Kim et al., 2019).

Every building construction project can follow the LEED BD+C system by choosing a specialty option or just following New Construction and Major Renovations for all the requirements (U.S. Green Building Council, 2013). The LEED BD+ C has several sub-systems including New Construction and Major Renovation, Core and Shell Development, Data Centers, Healthcare, Hospitality, Retail, Schools, Warehouses and Distribution Centers, and Multifamily Residential systems (U.S. Green Building Council, 2013). Among the sub-systems of LEED BD+C system, the most popular one is LEED for New Construction and Major Renovations (LEED-NC). This system is developed comprehensively in order to satisfy the various needs of different building types (Cheng & Ma, 2015).

LEED-NC version 3 consisted of seven credit categories including Sustainable Sites (25 points), Water Efficiency (10 points), Energy and Atmosphere (35 points), Materials and Resources (14 points), Indoor Environmental Quality (15 points), Innovation (6 points), and Regional Priority (4 points). However, significant changes were made in 2013 when LEED v4 was developed and the credit categories of LEED-NC changed into nine categories. The categories are Sustainable Sites (10 points), Water Efficiency (11 points), Energy and Atmosphere (33 points), Materials and Resources (13 points), Indoor Environmental Quality (16 points), Location and Transportation (20 points), Innovation (6 points), and Regional Priority (4 points). A building can be labeled depending on the LEED (BD+C) points it has received out of a possible 110.

As pointed out, the LEED systems have been updated over time to improve the evaluation criteria by enhancing their applicability. Therefore, it is necessary to study the applicability of this system by assessing the credits earned by the projects to identify the influential and most achievable credits in practice. Hence, in this study, the LEED-NC credit categories are investigated by evaluating the relationships between the credit categories and the overall scores achieved by some of the LEED projects that are similar in terms of the project type. Therefore, this study focuses on university residence halls that are certified under LEED-NC V3 (2009).

Method

Data Collection

In order to collect data from the USGBC website, all the projects having LEED-NC certification were listed. Since the number of LEED-NC projects in the United States is extremely high and the projects can have different purposes, only residence halls were chosen for this analysis to compare similar projects and provide a reliable evaluation. The 149 projects that were identified through the data collection included all the university campus residence halls that are certified under the LEED BD+C for New Construction system in the US by October 25, 2022. Among the 149 projects, the majority of them (n= 93) were certified under version 2009 (v3). The rest of the projects were either v2 or v4 and were removed because the criteria for the certification were different.

After removing the incompatible cases, the data were normalized to make sure that all the variables are using the same scale and providing accurate results. Next, in order to find the influential cases and outliers, the retained 93 cases were entered into a preliminary multiple linear regression (MLR) analysis to test the assumptions for the regression analysis by reviewing the behavior of the residual. As a result, five cases were identified as outliers due to having standardized residuals extremely close to either one or zero, and one project was identified as an influential case due to having a Cook's Distance of greater than 0.05. After removing the outliers and influential cases, 87 projects remained in the model (N= 87) to be considered for the data analysis.

Data Analysis

The dependent variable for this study was the LEED BD+C (NC) score of the projects and the independent variables are "Sustainable Site" (SS), "Water Efficiency" (WE), "Energy and Atmosphere" (EA), "Materials and Resources" (MR), and Indoor Environmental Quality (IEQ). These factors are the main credit categories for certifying a building under LEED BD+C for New Construction in Version 2009. After collecting and preparing the data, the relationship between each of these factors and the LEED score of the projects was assessed through MLR in order to find the independent effect that each of these categories has on the overall sustainability of the project. The findings were then summarized and the relationships were discussed and compared to their roles in determining sustainability as expected in the LEED-BD+C- NC system.

Multiple Regression Assumption Test

The MLR assumptions are lack of multicollinearity, normality of residuals, the linear relationships between each explanatory variable and the response variable, homoscedasticity, and independence of errors (Osborne & Waters, 2002; Gomez et al., 2013; Uyanık & Güler, 2013).

Both the linear relationships and the homoscedasticity assumptions were examined by reviewing the scatterplot of the predicted values of the dependent variable and the standardized residuals (Figure 1).

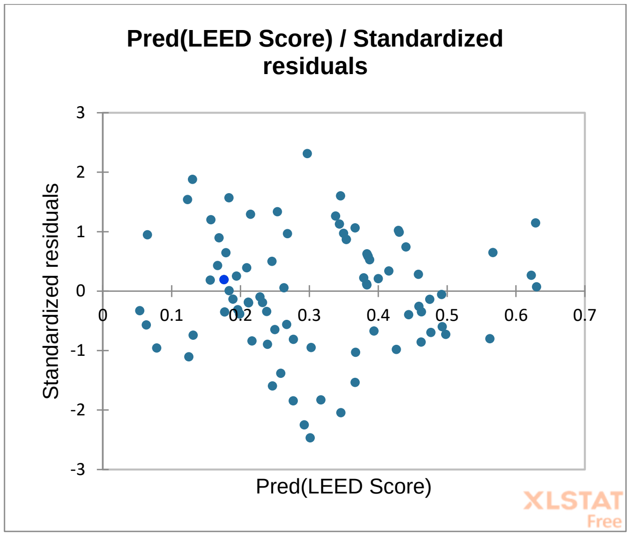

Figure 1. Residual plot

As shown in Figure 1, from the scatterplot it is evident that linear relationships exist between the variables. Furthermore, a lack of any clear pattern in the distribution of the residuals demonstrates the homoscedasticity of the data. The normality of residuals was assessed through a Shapiro-Wilk test (Table 1). The null hypothesis in this test is the normality of the residuals while according to the alternative hypothesis, the residuals are not normally distributed.

Table 1

The normality of residuals (Shapiro-Wilk test)

W	0.992
p-value (Two-tailed)	0.859
alpha	0.050

The p-value of greater than 0.05 shown in Table 2 indicates that the null hypothesis cannot be rejected, thus concluding that the residuals' distribution is normal.

The independence of errors was assessed using the Durbin-Watson test. In this test, the values between 1.5 and 2.5 (close to 2) show no considerable autocorrelation between the residuals. The Durbin-Watson value (Table 2) indicates the independence of errors (DW value = 1.845).

Table 2

Durbin-Watson Test Results

Autocorrelation	Statistic	p
0.163	1.845	0.097

An analysis of Tolerance and the Variance Inflation Factor (VIF) was conducted to test the lack of multicollinearity assumption. The VIF of lower than 10 and the Tolerance of greater than 0.1 indicates that multicollinearity is not an issue among the independent variables.

Table 3

Multicollinearity Test Results

	SS	WE	EA	MR	IEQ
Tolerance	0.860	0.886	0.953	0.961	0.936
VIF	1.162	1.129	1.049	1.040	1.068

Multiple Linear Regression Analysis

After ensuring that regression assumptions are met by the data, the relationships between the sustainability score of the 87 projects and their scores in SS, WE, EA, MR, and IEQ credit categories were evaluated through an MLR analysis (N=87). The descriptive statistics of the MLR analysis are shown in Table 4.

Table 4

Descriptive statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
LEED Score	86	0	86	0.041	0.673	0.310	0.140
SS	86	0	86	0.063	0.875	0.516	0.192
WE	86	0	86	0.000	1.000	0.605	0.248
EA	86	0	86	0.000	0.813	0.279	0.161
MR	86	0	86	0.000	1.000	0.432	0.204
IEQ	86	0	86	0.000	1.000	0.606	0.174

The goodness of fit statistics was first evaluated to understand the amount of variance in the LEED score that is explained by the five credit categories (Table 5). The R square of 0.926 (R2= 0.926) illustrates that the five independent credit categories explain 93% of the variability of the LEED NC Score.

Table 5

Goodness of fit statistics

Observations	86
Sum of weights	86
DF	80
R^2	0.926
Adjusted R^2	0.922
MSE	0.002
RMSE	0.039
MAPE	13.718
DW	1.845
Cp	6.000
AIC	-551.012
SBC	-536.286
PC	0.085

To test the statistical significance of the results, an analysis of variance (ANOVA) was conducted (Table 6). The results showed a statistically significant variance between the model mean and the LEED NC score (DF= 5; F= 201.391, p<.0001).

Table 6

Analysis of Variance

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	1.553	0.311	201.391	**<0.0001**
Error	80	0.123	0.002		
Corrected Total	85	1.677			

Computed against model Y=Mean(Y)

Finally, the standardized coefficient analysis was conducted to evaluate the magnitude and significance of the relationships between the total LEED score and the independent credit categories. According to table 7, the EA category has the strongest influence on the total LEED score (Coefficient=0.795, P-value<0.0001) among all the credit categories. The SS category is the second influential category on the total LEED score of the projects (Coefficient= 0.454, P-value<0.0001) followed by the MR category (Coefficient= 0.353, P-value<0.0001), IEQ category (Coefficient= 0.284, P-value<0.0001), and WE category (Coefficient= 0., P-value<0.0001), which shows the weakest positive influence on the sustainability score among all categories.

Table 7

Standardized coefficients

	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
SS	0.454	0.028	16.333	**<0.0001**	0.399	0.509
WE	0.283	0.031	8.594	**<0.0001**	0.202	0.324
EA	0.795	0.026	30.226	**<0.0001**	0.742	0.847
MR	0.353	0.033	10.570	**<0.0001**	0.287	0.420
IEQ	0.264	0.026	11.030	**<0.0001**	0.233	0.335

Discussion

The findings indicated that among all the studied credit categories, the Energy and Atmosphere category has the strongest influence on the overall LEED score of the projects. This finding was expected as this credit category accounts for 35 points out of 110 total points (32%). This finding supports that the important role that is considered for this credit category is consistent with what the projects have gained in achieving LEED certification. This demonstrates that achieving energy efficiency in buildings is both practical and influential in achieving community sustainability.

The Sustainable Site category was the second category showing a significant influence on sustainability. This category has also been emphasized in the LEED-NC system as a key determinant of sustainability by accounting for up to 26 potential points for improving different aspects related to the project site. Although the findings of this study have supported this important role, it is beneficial to discuss the consistency of this finding with the relevant existing literature and see if the direct and indirect effects of this factor are also consistent with the expected sustainability outcomes.

The Materials and Resources category was the third factor showing an influence on the overall sustainability level of LEED projects in this study. However, this category is the fourth largest credit category in the LEED-NC system in terms of the potentially available credits by accounting for a total of 14 potential credits. Accordingly, water efficiency, which has the lowest number of potential points by accounting for 10 credits in the LEED NC system is following Materials and Resources in this study. Indoor Environmental Quality, on the other hand, showed the lowest influence in determining the sustainability of studied projects while this credit category is the third largest category in the LEED NC system by accounting for 15 potential points.

The discrepancies between the importance of the credit categories from the LEED system standpoint and the influence they have on determining the overall LEED NC scores in practice highlight the need for more studies on the potential impact of these credits on sustainability. It also highlights the fact that the possibility of achieving some of the credits might be lower than others and assigning a high weight for them might not be practical. This might not only discourage the practitioners to attempt toward achieving those points, but it might also provide an unbalanced certification system that does not show internal consistency. Therefore, the Green Building Certification Institute should either change the criteria for achieving these points or reduce the number of points that can be achieved by meeting the current criteria and allocate the remaining points to the credits that are more practically achievable.

Overall, this study demonstrates that the LEED-ND system should reconsider the weighting for some of the factors and redevelop the measures for the evaluation of some credits. Given the points that were discussed in this study, there is a need for further studies that expand the knowledge about the practicability of the LEED-NC criteria and their application in assessing the sustainability level of the projects.

Conclusion

This study evaluated the relationship between the LEED NC score and some of the key credit categories in determining the sustainability of projects. The purpose of the study was to find the harmony between the expected and the actual influence of these credit categories in determining the sustainability of a project. The findings of the study showed some harmony and some inconsistencies. The credit categories of Energy and Atmosphere and Sustainable sites showed the harmony between the expected and actual influences on the overall sustainability level. However, the three credit categories of Materials and Resources, Indoor Environmental Quality, and Water Efficiency did not show any harmony between the expected and the actual influence on determining the overall sustainability level of projects.

The findings highlight the potential need for re-evaluating the criteria under the three categories that did not show consistency between the expected and the actual influence on determining sustainability. The limitation of this study is the number of projects that have been studied for evaluating the relationships between the achieved points and the total sustainability scores. However, as discussed in the introduction, the reason for the limited number of studied cases was that the authors compared the projects with the same use (residence halls) so that the application of the LEED criteria could be comparable and provide a reliable outcome. This limitation provides the opportunity for future research that consider a larger group of similar projects that share common credits for certification.

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