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Assessing LEED Credit Weighting: A Dual Perspective on Sustainable Construction and Educational Implications

Dr. Mohsen Goodarzi, Ball State University

Dr. Mohsen Goodarzi is an assistant professor of construction Management at Ball State University. He received his Ph.D. in Construction Management from Michigan State University in 2021. His research focuses on green building, sustainable built environment, life cycle costing, and construction education.

Dr. Mohsen Garshasby, Mississippi State University

Mohsen Garshasby is an Assistant Professor in the Department of Building Construction Science at Mississippi State University. Dr. Garshasby is an architect, researcher, and educator who currently teaches collaborative studio(s) and environmental building systems within the College of Architecture, Art and Design at Mississippi State University.

Assessing LEED Credit Weighting: A Dual Perspective on Sustainable Construction and Educational Implications

Mohsen Goodarzi[1], Mohsen Garshasby[2]
[1]Assisstant Professor, Department of Construction Management and Interior Design, Ball State University
[2]Assistant Professor, Building Construction Science, Mississippi State University

Abstract:
This research investigates the relationship between Leadership in Energy and Environmental Design (LEED) version 3 credit categories and the overall LEED score of multifamily residential projects to discern the actual contribution of each credit category in achieving the overall LEED score of the projects. The study compares the actual and the expected contribution of each category in achieving the overall LEED score to understand the success of this system in providing realistic and practical criteria for evaluating building sustainability and discuss the implications of the findings for sustainable construction education. Data regarding LEED-certified projects was collected from the U.S. Green Building Council (USGBC) website and analyzed using multiple regression analysis. The results indicate that the actual contributions of Energy and Atmosphere, Sustainable Sites, and Indoor Environmental Quality align with their expected contributions, whereas inconsistencies are observed between the actual and expected contributions of Water Efficiency and Materials and Resources categories. These findings help sustainable construction educators use the lessons learned from current and past projects to highlight the potential barriers to achieving sustainability goals in construction and include strategies to overcome these barriers in the course curriculum.

Key Words: LEED, Sustainable Construciton, Credit Category, Construction Education

Introduction

Numerous green building certification programs exist, with Leadership in Energy and Environmental Design (LEED) standing out as one of the most widely recognized systems. LEED functions as a certification program that assesses building sustainability by offering a framework for the design, construction, and operation of green buildings (Wu et al., 2016). In addition to establishing standards for evaluating building performance, LEED offers several other benefits, including opportunities for sustainable construction education (Goodarzi, 2023) fostering the development of sustainable technologies, stimulating research and development in green technologies, and inspiring the construction of green buildings (Pham et al., 2020).

The United States Green Building Council (USGBC) has demonstrated a longstanding commitment to developing an evaluation system capable of accurately assessing the performance of green buildings (Lei & Cui, 2022). Since the launch of the LEED pilot in 1998, there have been numerous updates to the LEED systems driven by technological advancements and changes in regulations and policies. The most current iteration, Version 4.1, has undergone updates from some credits included in LEED Version 4. Introduced in 2013, LEED Version 4 significantly altered the criteria for evaluating building sustainability compared to its predecessor, LEED Version 3 (2009). However, despite these updates, the number of projects certified under LEED

Version 3 remains higher than all other versions. In both Versions 3 and 4, projects can earn a maximum of 110 points based on their adherence to LEED standards. The LEED certification program operates on a point-based system: if a project accrues 40 points or more, it qualifies as LEED-certified. Subsequently, LEED Silver certification is attainable with 50-60 points, while LEED Gold certification requires between 60 and 80 points. Projects that amass more than 80 points qualify for LEED Platinum certification, the highest level of LEED certification. Under the LEED umbrella, various rating systems exist, with one of the most comprehensive being LEED for Building Design and Construction: New Construction (LEED-BD+C: NC). This rating system was developed to accommodate the diverse requirements of different building types (Cheng & Ma, 2015). In the LEED NC V3 rating system, seven categories have been established: Sustainable Sites (SS; 26 points), Water Efficiency (WE; 10 points), Energy & Atmosphere (EA; 35 points), Materials & Resources (MR; 14 points), Indoor Environmental Quality (IEQ; 15 points), Regional Priority (RP; 4 points), and Innovation (IN; 6 points).

Given its comprehensiveness and significance, the authors of this study have conducted several investigations into different LEED systems and their effectiveness in establishing practical and realistic evaluation criteria for building sustainability. For Instance, Goodarzi et al. (2023) assessed the consistency between the weights assigned to each credit category in LEED NC version 3 and their actual impact on defining the sustainability level of certified projects. They identified inconsistencies between the expected and actual effects of certain categories, suggesting the need for further studies across different versions and project types. In another study, Goodarzi and Shayesteh (2024) utilized structural equation modeling to examine the relationships between credits and the overall LEED score in LEED v4. They aimed to understand the impact of each credit within its category, as well as the cumulative effect of all credits within each category on the overall LEED score. Similarly, Goodarzi and Garshasby (2024) conducted a study parallel to the present one, focusing on LEED NC v4, with a particular emphasis on multifamily residential projects. They discovered inconsistencies between the anticipated and actual contributions of credit categories, such as Indoor Environmental Quality exhibiting a greater influence on the overall LEED score compared to Location and Transportation, despite having a lower weight in the system. LEED for Neighborhood Development (LEED-ND) was also studied by Goodarzi and Berghorn (2024), and it was demonstrated that walkability had no significant relationship with the overall LEED score despite being highlighted as one of the most important sustainability measures in the LEED system and other studies.

Other researchers have also conducted studies on the factors affecting the achievement of LEED credits. Ma and Cheng (2016), for instance, explored the attainment of individual credits in previous LEED-certified projects, revealing that certain credits, such as those related to rapidly renewable materials and material reuse, were seldom achieved. Wu et al. (2017) conducted a critical examination of the points acquired by LEED v3 certified projects, evaluating the credit allocation pattern based on various parameters such as geographic location, certification level, and building types. Their study revealed differing performance across different building sectors in Sustainable Sites, Water Efficiency, and Indoor Environmental Quality, and identified issues related to point chasing in Materials and Resources credits.

Despite several studies on LEED systems and credits, the educational role of the findings has not been discussed adequately. Additionally, given the comprehensive nature of the LEED system, project types have not been adequately considered as a significant factor in evaluating credit achievement. Therefore, this paper addresses this gap by taking project type into account and aims to explore the relationships between LEED NC v3 credit categories and the overall LEED scores achieved by multifamily residential projects. The study also seeks to examine the consistency between the weight assigned to each credit category in this system and the actual contribution of each category to determining the overall sustainability score. The findings of this study are expected to offer insights into credit designation for future versions of the system and help sustainable construction educators use the lessons learned from current and past projects to highlight the potential barriers to achieving sustainability goals in construction and include strategies to overcome these barriers in the course curriculum.

Method

Data Collection

The focus of this study was on multifamily residential projects certified under LEED-NC version 3. To gather data from the USGBC website, the first step involved compiling a list of all projects in the United States with LEED-NC certification, which were then filtered by version. After filtering, a total of 8200 projects certified under version 3 were identified. These projects were further categorized by project type, with only multifamily residential projects selected, resulting in 844 projects certified by February 1, 2024.

Following an initial screening, 12 projects were found to have missing data and were consequently excluded from the dataset, leaving 832 projects for analysis. Subsequently, outliers were identified based on standardized residuals below -3 or above 3 and removed from the dataset. Cook's Distance test was then applied to detect influential outliers, with a threshold set at 0.05. This led to the removal of 30 additional projects, either due to being outliers or having a Cook's Distance exceeding 0.05. Ultimately, 802 projects remained for further data analysis.

Data Analysis

This study examined the relationship between projects' overall LEED NC scores, serving as the dependent variable, and the credit categories of the LEED NC v3 system, acting as predictors. These predictors included "Sustainable Sites" (SS), "Indoor Environmental Quality" (IEQ), "Materials and Resources" (MR), "Energy and Atmosphere" (EA), and "Water Efficiency" (WE). Multiple regression analysis (MLR) was employed as the analytical method to assess these relationships, aiming to determine whether the anticipated impact of each credit category on the projects' overall sustainability aligned with its actual effect.

To ensure the reliability and accuracy of the findings, it was crucial to verify whether the data met the assumptions of the MLR test. Thus, the MLR assumptions were initially assessed. XLSTAT was utilized as software for conducting the data analysis, facilitating unbiased and precise results.

Multiple Regression Assumption Test

The assumptions of MLR include the absence of multicollinearity, normal distribution of residuals, linear relationships between each predictor and the response variable, homoscedasticity, and independence of errors. (Osborne & Waters, 2002; Uyanık & Güler, 2013). To examine the homoscedasticity and linear relationship assumptions, a scatterplot of the standardized residuals against the dependent variable was analyzed. Figure 1 illustrates this scatterplot, revealing linear associations between variables. However, it also suggests a lack of homoscedasticity, as there is no discernible pattern in the distribution of residuals.

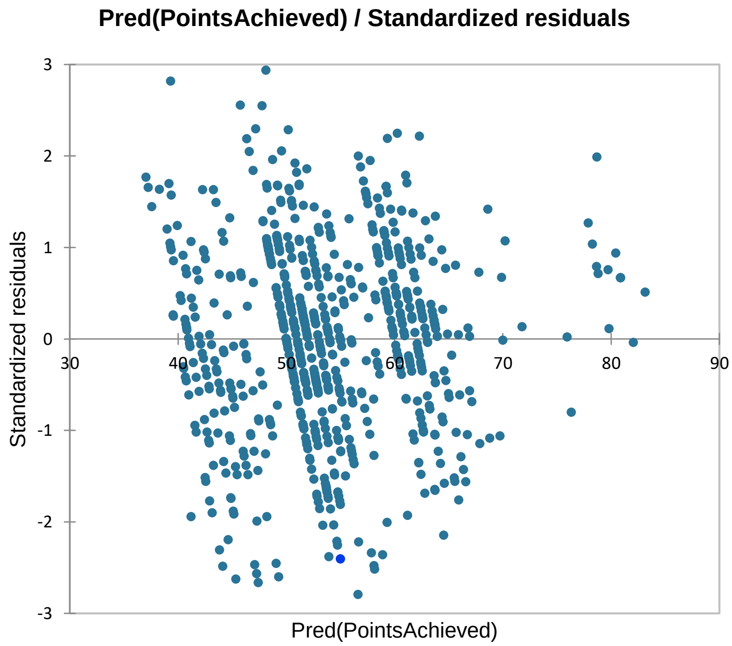

Figure 1. Residuals plot

Subsequently, a Shapiro-Wilk test was administered to assess the normality of residuals (Table 1). This test assumes that the residuals follow a normal distribution. If the null hypothesis is upheld, indicating that the p-value exceeds the significance level (alpha=0.05), it suggests that the data's distribution is normal. In this case, since the computed p-value surpasses the significance level, the null hypothesis cannot be refuted, indicating that the residuals indeed adhere to a normal distribution.

Table 1. The normality of residuals (Shapiro-Wilk test)

W	0.996
p-value (Two-tailed)	0.076
alpha	0.050

A Durbin-Watson test was performed to examine the independence of errors (Table 2). The value of 1.995 suggests the absence of autocorrelation among the residuals. Notably, when the Durbin-Watson value falls within the range of 1.5 to 2.5, it indicates the absence of autocorrelation among the residuals. The optimal value for this statistic is 2.00, and the closer the obtained result is to this figure, the lower the likelihood of autocorrelation among the residuals.

Table 2. Durbin Watson Test

Autocorrelation	Statistic	p
0.181	1.995	0.772

Finally, the collinearity among the variables was assessed using Tolerance and Variance Inflation Factor (VIF) analysis. As depicted in Table 3, the results demonstrate the absence of multicollinearity among the independent variables. This is evidenced by all variables having a VIF less than 10 and a Tolerance greater than 0.1.

Table 3. Multicollinearity Test Results

	SS	WE	EA	MR	IEQ
Tolerance	0.991	0.984	0.981	0.959	0.945
VIF	1.009	1.016	1.019	1.043	1.058

Multiple Linear Regression Analysis

Following the assessment of assumptions, it became clear that the data fulfilled all the required criteria. Consequently, the next step involved performing MLR to examine the associations between the credit categories and the overall LEED NC score of multifamily residential projects certified under the LEED NC v3 system. Table 4 presents the descriptive statistics of the dataset.

Table 4. Descriptive Statistics

Variable	Obs.	Min.	Max.	Mean	Std. deviation
LEED Score	802	38.000	84.000	53.938	7.814
SS	802	6.000	26.000	20.076	2.662
WE	802	0.000	10.000	5.045	1.913
EA	802	0.000	31.000	9.979	4.978
MR	802	0.000	10.000	4.665	1.602
IEQ	802	3.000	13.000	7.420	1.727

The goodness of fit statistics, displayed in Table 5, indicate that 96% of the variance in the LEED NC overall score is accounted for by the five independent variables (credit categories) (R^2 = .958). An R^2 exceeding 0.7 signifies a well-fitted model, suggesting that the model effectively explains variations in the dependent variable.

Table 5. The goodness of fit statistics

Observations	802
Sum of weights	802
DF	796
R^2	0.958
Adjusted R^2	0.958
MSE	2.569
RMSE	1.603
MAPE	2.441
DW	2.003
Cp	6.000

AIC	762.806
SBC	790.929
PC	0.042

The results from the analysis of variance (ANOVA), presented in Table 6, indicate that there was a statistically significant difference between the model mean and the LEED NC overall score (DF= 5; F= 3647.499, pValue<0.0001). In simpler terms, with a p-value less than 0.0001 as computed in the ANOVA table, and considering a significance level of 5%, it suggests that the information provided by the explanatory variables significantly improves upon what a basic mean would offer.

Table 6. Analysis of Variance

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	46859.631	9371.926	3647.499	**<0.0001**
Error	796	2045.252	2.569		
Corrected Total	801	48904.883			

Computed against model Y=Mean(Y)

Finally, the evaluation of the relationships between independent and dependent variables involved conducting a standardized coefficient analysis. Table 7 presents the results of this analysis, aiding in the comprehension of the actual contribution of each credit category in the overall LEED NC score attained by multifamily residential projects. According to the results of this analysis, the EA category exhibits the most strong correlation with the overall LEED NC score (coefficient = 0.678), followed by the SS category (coefficient = 0.402), IEQ category (coefficient = 0.260), WE category (coefficient = 0.251), and MR category (coefficient = 0.226) in decreasing order of strength.

Table 7. Standardized Coefficients

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
SS	0.402	0.007	55.272	**<0.0001**	0.388	0.416
WE	0.251	0.008	32.093	**<0.0001**	0.236	0.266
EA	0.678	0.008	89.504	**<0.0001**	0.664	0.693
MR	0.226	0.008	29.374	**<0.0001**	0.211	0.241
IEQ	0.260	0.007	35.113	**<0.0001**	0.245	0.274

Discussion

This study investigated the correlations between the LEED NC v3 credit categories and the overall LEED NC score of multifamily residential projects certified by February 1, 2024. The aim was to assess whether the weight assigned to each credit category aligns with the actual contribution of the credit category in meeting LEED sustainability requirements and to discuss the potential obstacles in achieving the credits that did not perform as expected. The results of the study revealed that among the examined credit categories, the Energy and Atmosphere category made the most significant contribution to the overall LEED NC score for multifamily residential projects. Given that this category carries the highest weight in the LEED NC system, accounting for 35 out of 110 overall LEED NC v3 scores, it was expected to have the greatest impact on achieving sustainability in the studied projects. This outcome underscores the coherence between the attainability of credits under this category and the weight assigned to it, thus indicating the establishment of pragmatic and feasible criteria for sustainability achievement through meeting Energy and Atmosphere requirements and credits. This conclusion aligns with the findings of Goodarzi and Garshasby (2024), who examined LEED NC version 4, suggesting that the EA category is realistically formulated in both versions.

The second category demonstrating a significant impact on achieving LEED NC v3 certification for multifamily residential projects was Sustainable Sites. This category comprises 26 points out of the total 110 achievable credits by the projects and ranks as the second largest category within the LEED NC v3 system. It was anticipated that this category would wield substantial influence, given its position as the second-ranking category in the LEED NC v3 system after the EA category. However, since this category is divided into two categories in version 4.0, direct comparison with similar studies on version 4.0 is not feasible. Nevertheless, this finding underscores the alignment between the weight assigned to this category within the system and its actual contribution to achieving the overall LEED score.

Indoor Environmental Quality ranks third in contributing to the overall LEED score in this version. This result aligns with the anticipated impact of this category within the system, indicating that, unlike in version 4, the weight assigned to this credit category is realistic and attainable as anticipated. This finding differs from the conclusions drawn by Goodarzi et al. (2023), where Indoor Environmental Quality was found to be the least influential category in determining the overall LEED NC score of university residence halls.

Although the first, second, and third credit categories showed consistency between the expected and actual contributions, an inconsistency exists between the anticipated and actual contributions of the fourth and the fifth categories to achieving LEED scores. In LEED NC v3, the Materials and Resources Category holds the fourth highest weight, accounting for 14 points, while Water Efficiency is ranked fifth with 10 points. However, this ranking is not reflected in the findings of this study, indicating a mismatch between the expected and actual contributions of these two categories to the overall LEED score. This inconsistency between the points attained by LEED-certified projects and the assigned weight to these categories may stem from inadequate weighting criteria for certain categories, underscoring the need for periodic review of LEED standards and incorporation of insights from existing certified projects. This finding is in line with Da Silva and Ruwanpura (2009) indicating that the Materials and Resources category was the lowest credit category in terms of credit achievement.

The discrepancies highlighted above indicate that certain credits offer greater opportunities for achievement than others. The findings suggest that some credit categories may be more appealing to projects because stakeholders perceive them to add more value. Additionally, the cost associated with meeting credit requirements can significantly influence credit attainment. It is crucial to consider cost when evaluating the correlation between points and overall LEED NC scores, as some points may entail higher expenses, making them less desirable for developers to pursue. Therefore, these factors should be taken into account when assessing the actual impact of each credit on achieving the overall LEED NC score. Despite cost serving as a significant barrier to achieving certain credits, it should be factored into the development of criteria and assignment of weights to motivate practitioners to pursue these credits. This can be achieved by involving project stakeholders in decision-making processes and engaging them in the development of sustainability criteria for the system.

Conclusion

While the findings of this study suggest a potential lack of practicality and comprehensiveness in developing evaluation criteria for two LEED categories, it provides opportunities for evaluation of several external contributing factors, such as the impacts of the pandemic and associated issues like supply chain disruptions, material availability, labor constraints, and cost escalation. The findings highlight the need for further studies to explore the underlying reasons behind this study’s findings.

Furthermore, given that research-informed teaching is known to be effective in improving the quality of teaching, it is important to include the findings of practical studies, like this research, in the sustainable construction course contents. The implications of these findings for sustainable construction education are significant. Incorporating the insights gained from this research into sustainable construction courses can enhance students' understanding of the practical challenges and opportunities associated with achieving LEED certification. For example, educators can use the study's results to illustrate the importance of energy efficiency and sustainable site development in project planning and design. By highlighting the substantial impact of the Energy and Atmosphere and Sustainable Sites categories on the overall LEED score, educators can emphasize the need for a holistic approach to sustainability that integrates various environmental considerations.

Moreover, the discrepancies observed in the Materials and Resources and Water Efficiency categories highlight the importance of critically evaluating the weighting of different sustainability criteria. Educators can use these findings to encourage students to think critically about the allocation of resources and the trade-offs involved in meeting different sustainability goals. This can involve discussions on the economic and practical feasibility of achieving certain credits and the role of cost considerations in shaping sustainability strategies. By incorporating these insights into the curriculum, educators can prepare students to navigate the complexities of sustainable construction and make informed decisions that balance environmental, economic, and social considerations.

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