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Addressing challenges in LEED green building ratings in Türkiye

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Professional paper

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Addressing challenges in LEED green building ratings in Türkiye

This study examined the effectiveness of the LEED green building rating system and identified performance gaps in developing countries using Türkiye as a case study. The analysis of 134 LEED Platinum V4-certified buildings in Turkiye revealed discrepancies in high-priority sites, site evaluation, building product definition and optimisation, and low-emission material credits compared with other countries. Variations in energy, atmosphere, and indoor environmental quality criteria were also noted within LEED Platinum-certified buildings in Turkiye. The study concludes that while LEED is widely embraced, local standards and contextual factors must be considered when implementing these programs.

Key words:
green building, LEED rating system, credit achievement, statistics method

Stručni rad

Tugce Pekdogan

Suočavanje s izazovima u vezi s ocjenjivanjem zelene gradnje prema LEED-u u Turskoj

U ovom je radu ispitana učinkovitost LEED sustava ocjenjivanja zelene gradnje i utvrđeni su nedostaci u provedbi takvog sustava ocjenjivanja u zemljama u razvoju, pri čemu je za analizu slučaja odabrana Turska. U odnosu na druge zemlje, analiza 134 zgrade s platinastim certifikatom LEED V4 u Turskoj pokazala je odstupanja u prioritetnim lokacijama, ocjeni lokacije, definiciji i optimizaciji građevnog proizvoda te bodovima u vezi s materijalima s niskim emisijama. Razlike u kriterijima u pogledu energije, atmosfere i kvalitete unutarnjeg okoliša također su primijećene među zgradama s platinastim certifikatom LEED u Turskoj. Istraživanje pokazuje da, iako je LEED općeprihvaćen, pri provedbi ovih programa moraju se uzeti u obzir lokalni standardi i kontekstualni čimbenici.

Ključne riječi:
zelena gradnja, LEED sustav, dodjela bodova, statistička metoda

1. Introduction

As cities continue to grow and urbanisation accelerates, addressing the impact of buildings on the environment becomes increasingly crucial. With buildings accounting for a significant amount of a country's total energy consumption and greenhouse gas emissions, countermeasures must be implemented to reduce their negative environmental impact. Reducing the negative effects of buildings on the environment is an increasingly important problem worldwide. Along with a global effort to mitigate climate change, measures are being implemented to make buildings more energy-efficient and sustainable. Globally, greenhouse gas emissions sources include the production of electricity and heat (31 %), agriculture (11 %), transportation (15 %), forestry (6 %), and manufacturing (12 %), according to the World Resources Institute [1]. Energy production of all types accounts for 72 % of all emissions. In 2015, the construction and operation of buildings were responsible for 38 % (13.1 gigatons) of global energy-related CO_2 emissions. However, in 2020, the industry's CO_2 emissions fell by an estimated 10 % to 11.7 gigatons, a level not seen since 2007. This decline was mainly attributed to reduced energy demand during the COVID-19 pandemic and continued decarbonisation efforts in the power sector [2]. The COVID-19 pandemic in 2020 had an impact on the global construction industry. Sites being emptied during lockdowns, material supply disruptions, and shutting down of public services and buildings decreased the construction growth rate worldwide by 4 % compared to 2019. In response to the impact of the pandemic on the construction industry, many countries implemented economic stimulus policies and packages to support buildings and the construction industry, aiming to revitalise the sector and address the challenges posed by the pandemic. However, promoting building sustainable structures in line with globally determined environmental goals is crucial [3].

According to the Paris Agreement, reducing emissions, adapting to the effects of climate change, and increasing climate resilience without harming food production are among the main objectives. Among the Nationally Determined Contributions (NDCs) within this agreement, improving building energy efficiency is the second most frequently cited policy after using renewable energy in the energy sector [4]. Concerning the energy distributions for energy supply, transport, buildings, industry, and cross-cutting/other categories, renewable energy generation for energy supply is 84 %, and energy efficiency improvement is 45 % for transport. The improvement in multi-sector energy efficiency was 48 % for energy efficiency.

With the worldwide expansion of these commitments, sustainable building practices have considerably contributed to achieving global climate targets. In line with global commitments to sustainability, buildings are being designed with a focus on energy efficiency and indoor quality. Concurrently, innovative systems are being developed to reduce carbon footprints and energy needs and increase the use of renewable energy sources. Integrating advanced materials and technologies further aligns these efforts with international climate targets. Construction industry practices such as using environmentally friendly materials, greenery systems, efficient waste management, and sustainable water use are important components in constructing environmentally friendly buildings [5, 6]. Collaboration among governments, policymakers, and construction industry stakeholders is particularly important for developing and implementing regulations that promote sustainable building practices, leading to the creation of green building standards and certifications, such as the Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Green Star, Ecological and Sustainable Design in Buildings (BEST), and the German Sustainable Building Council (DGNB).

Energy efficiency measures include using efficient lighting and heating systems, applying insulation and smart building technologies, and adopting green building principles. These measures reduce greenhouse gas emissions and provide cost savings for the building occupants. In addition, using sustainable building materials reduces the environmental footprint of buildings. Using sustainable materials such as recycled or locally sourced materials reduces carbon in construction, whereas construction techniques that prioritise minimising waste and optimising resource use significantly affect a building's environmental performance. Governments and policymakers play a crucial role in promoting sustainable buildings. Financial incentives and subsidies encourage the adoption of sustainable technologies and practices.

Consequently, the focus on energy efficiency and sustainability has increased in the global agendas of the building industry. Considering that the building sector in Turkiye accounted for the highest final energy consumption rate (32.8 %) in 2015, numerous studies have focused on devising ways to minimise energy usage in buildings [7-9]. Many countries have adopted various sustainable building rating systems that reflect a global commitment to energy efficiency and sustainability in construction. These systems, as outlined in Table 1, include national and international frameworks such as BEST in Turkiye, BREEAM in the United Kingdom, CASBEE in Japan, DGNB in Germany, Green Star in Australia, HQE in France, LEED in the USA, and MOHURD in China. Although these systems are not obligatory standards, they provide influential global guidelines and benchmarks for sustainable building practices (Table 1).

The world's most widely used green building certification programmes, BREEAM and LEED, also play a vital role in reducing the negative impact of buildings on the environment [10]. LEED is one of the most popular green building certification programmes employed in Turkiye and worldwide, with more than 96,329 LEED projects in 167 countries and regions [11]. The LEED rating system is available for any building project type, including new construction, core and shell, data centres, warehouses and distribution centres, hospitality, schools, retail, and healthcare. In addition, this system provides a framework

Table 1. Sustainable building rating systems of national/international agencies

Standards	Country
Ecological and Sustainable Design in Buildings (BEST)	Turkiye
Building Research Establishment Environmental Assessment Method (BREEAM)	United Kingdom
Comprehensive Assessment System for Built Environment Efficiency (CASBEE)	Japan
German Sustainable Building Council (DGNB)	Germany
Green Star	Australia
High-Quality Environmental (HQE)	France
Leadership in Energy and Environmental Design (LEED)	USA
The Ministry of Housing and Urban-Rural Development (MOHURD)	China

for projects to create sustainable buildings with this certification to reduce the negative effects on the environment and energy consumption. In the LEED system, buildings earn certificates on four levels: certified (40–49 points), silver (50–59 points), gold (60–79 points), and platinum (80+ points), representing the sums of the points earned from each credit category. The highest possible score was 110. This system has been used for over 20 years and consistently improved over previous versions (v2009, v4, and v4.1) [11]. LEED version 4 was valid from June 2014 to June 2019. The LEED rating system V4 and the previous version, V2009, have been completely updated. In 2019, the certification system was updated to V4.1 based on existing credit requirements.

In the past decade (January 2013 to December 2023), 73,981 projects in 148 countries/regions were awarded LEED certificates at different levels. Of these, 7,855 projects held platinum certificates of 80 points or more, 25,290 projects held gold certificates of 60–79 points, 19,974 projects held silver certificates of 50–59 points, and 20,862 projects held certified certificates of 40–49 points (see Figure 1). Turkiye ranks 11th among countries/regions with the highest number of LEED projects worldwide (556) [11].

The LEED certification evaluation criteria are scored in the categories of Location and Transportation (LT), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (EQ), Innovation (ID), and Regional Priority (RP) depending on the certification types of V4. In this segmentation, the Integrative Process Credit earns one point, LT 20 points, SS 10 points, WE 11 points, and EA 33 points.

Many researchers have examined the scores of buildings certified by the LEED systems, with several studies conducted on the LEED-NCv4 criteria for all rating headings. Recent review studies on headings from the LEED rating system were summarised, with an overview of their general inferences presented in Table 2, which provides an overview of the literature on the various LEED-NCv4 criteria. Table 2 highlights the use of GIS analysis for site selection in the first category, LT, and the potential for a combination of methods, such as BIM and Web Map Systems for LT. Another category, SS, discusses the integration of dynamic modelling for green building design while discussing the specifications required to minimise the heat island effect. The WE category extensively examines the contribution of LEED implementation to WE based on the United Nations Sustainable Development Goals (SDGs) and the Comprehensive Contribution to Development Index (CCDI). This category also emphasises the importance of considering the climate and geographical location in conservation efforts.

Further research on the energy and atmosphere categories should explore strategies to overcome the challenges of the global adoption of LEED. In addition to studies of materials and resources, local practices in different countries can be compared and examined. The EQ category refers to the higher energy consumption rates observed in LEED-certified buildings but increased satisfaction in terms of overall comfort. In addition, for the EQ category, we investigated the relationships between building design, temperature comfort, aesthetics, and occupant perceptions of productivity and satisfaction. Additionally, this research could examine

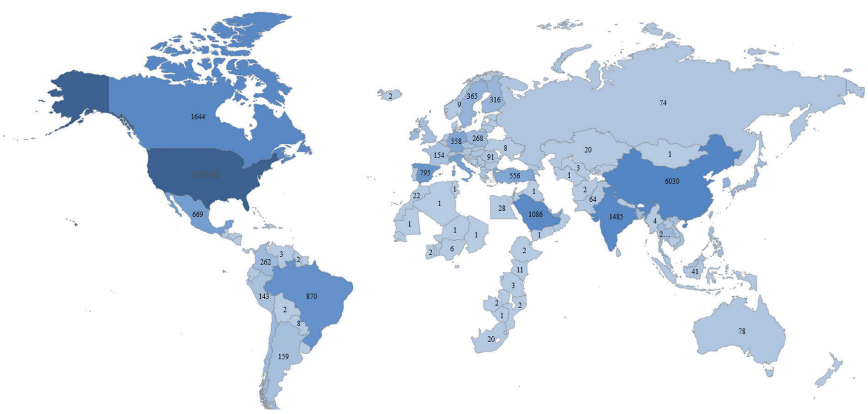

Figure 1. Worldwide LEED certification numbers

Table 2. Overview of the past reviews

LEED v4 criteria	Reference	Investigation approach
Location and Transportation (LT)	[12]	Study methodology: Utilised Geographic Information Systems (GIS) for decision-making in LEED's LT criteria. Main finding: GIS analysis shows significant potential in site selection for LEED credits, particularly in newly developed areas.
	[13]	Study methodology: Integrated Building Information Modelling (BIM) and Web Map Service (WMS) technologies for LT analysis. Main finding: Combining these technologies and specific plugins can expedite the LT certification process using the Autodesk Revit API and the Google Maps API
	[14]	Study methodology: Analysed various mobility and parking management techniques within the LT criteria. Main finding: Emphasises the need for strategies that discourage driving, such as parking pricing and for commuters.
Sustainable Sites (SS)	[15]	Study methodology: Conducted a pilot study of two generations of city development in Ramadan City and Badr City, Egypt. Main finding: Badr City has more sustainable areas, attributed to better land use, public transport access, parking space reduction and open space.
	[16]	Study methodology: Performed an interprofessional survey in South-West Nigeria focusing on LEED awareness for green housing development. Main finding: Highlighted a significant awareness of LEED requirements, especially in the SS category, followed by innovation and regional priority.
	[17]	Study methodology: Implemented dynamic modelling to evaluate site-dependent credits in LEED under the LT and SS categories. Main finding: Revealed that appropriate site selection can significantly impact LEED point-scoring, potentially achieving 63% of total available points.
	[18]	Study methodology: Investigated the specific combinations of concrete ingredients to minimise the heat island effect. Main finding: Identified the impact of cement on reducing the solar reflectivity of concrete.
Water Efficiency (WE)	[19]	Study methodology: Conducted a statistical analysis of water consumption in LEED vs. non-LEED buildings. Main finding: No significant difference in water usage, suggesting a performance gap in LEED buildings.
	[20]	Study methodology: Utilised the United Nations' Sustainable Development Goals (SDGs) Comprehensive Contribution to Development Index (CCDI). Main finding: Assessed contributions of implementing LEED v2.2 toward WE.
	[21]	Study methodology: Analysed water reduction potential using the Estidama Pearl rating system and LEED-certified building in Abu Dhabi. Main finding: Identified 22% and 36% water reduction potential in selected buildings.
	[22]	Study methodology: Reviewed the adaptation of the 'WE' category in the LEED system in developing countries, considering regional differences and local conditions. Main finding: Identified practices and strategies to enhance WE, informing practitioners in developing countries about green-building certification related to WE.
	[23]	Study methodology: Conducted a literature analysis and semi-structured interviews with two LEED-certified hotels in Sri Lanka to explore WE practices. Main Finding: Developed a framework comparing WE practices in LEED-certified hotels globally and in Sri Lanka, identifying discrepancies in the applicability of LEED's WE requirements.
Energy and Atmosphere (EA)	[24]	Study methodology: Investigated the relationship between project size and EA credits in U.S. office buildings V3 and V4 projects. Main finding: Revealed the significance of project scale in establishing LEED methods.
	[25]	Study methodology: Reviewed and compared the existing codes, standards, and regulations in India, Abu Dhabi, and Turkiye with their U.S. counterparts in this category. Main finding: These countries have adapted U.S. and U.K. standards to local conditions, reflecting varying stages of development and challenges in implementing green building certification systems due to differences in standard quality and coverage.

Table 2. Overview of the past reviews- continuation

LEED v4 criteria	Reference	Investigation approach
Energy and Atmosphere (EA)	[26]	Study methodology: Analysed this LEED v3 2009 NC category in various European countries, focusing on credit performances and how they vary according to local conditions. Main findings: While LEED's EA category is significantly emphasised, its application in EU countries reveals diverse credit patterns influenced by local practices and conditions, offering valuable insights for practitioners.
Materials and Resources (MR)	[27]	Study methodology: Conducted a comparative analysis of local practices in selected developing countries against the MR category of LEED v4 certification, focusing on issues like waste management, resource sourcing, and sustainable material use. Main findings: LEED's MR standards face challenges in developing countries owing to local practice variations. Guidelines are provided to aid practitioners in green-building certification.
	[28]	Study methodology: Evaluated the process and challenges of obtaining certification for construction materials in Brazil, focusing on the soil-cement-waste block, by analysing reports from recognised entities and promoting information sharing among builders. Main findings: Soil-cement-waste blocks, made from recycled ingredients, exceed LEED certification requirements and offer a sustainable, cost-effective, and eco-friendly construction solution, scoring up to 13 points.
Indoor Environmental Quality (EQ)	[29]	Study methodology: Compared energy consumption and occupant comfort in a LEED-certified residential college building to non-LEED-certified buildings on a university campus. Collect data on physical features, weather, utility consumption, occupancy, and survey occupant satisfaction in comfort areas. Main findings: LEED-certified buildings had higher energy consumption but better occupant comfort and satisfaction due to lower LEED EA and higher EQ scores.
	[30]	Study methodology: Evaluated EQ in U.S. workplaces by comparing occupant satisfaction and performance across seven EQ criteria between LEED-certified and non-LEED-certified buildings. Main findings: LEED-certified buildings are better in IAQ, office furnishings, and cleanliness, but non-certified ones perform better in office layout, lighting, and acoustics, suggesting that LEED's EQ criteria need refinement.
	[31]	Study methodology: Evaluated EQ in LEED-certified Midwest homes using a mail-in survey. Two hundred thirty-five residents responded to 13 IEQs, analysed via gap analysis. Main findings: Found gaps in temperature, air quality, and humidity management in LEED-certified homes. Daylight and artificial lighting were satisfactory.
	[32]	Study methodology: Studied occupant productivity in LEED-certified healthcare buildings. Main finding: Positive correlation with building design, temperature comfort, and space usage.

strategies to improve cleanliness, acoustic quality, and other factors that affect EQ.

Notably, all the aforementioned studies on different LEED versions analysed the issue of certification/category/credit achievement scores, highlighting the difficulty of implementing LEED worldwide due to varying local standards and economic, technological, and social diversity. The quality, content, and diversity of standards require different approaches in each country. To implement green-building certification systems, the characteristics of the regions to which they are applied should be considered. This study aims to examine Turkiye's position among these building certification systems by first evaluating 134 new buildings in the world that have LEED Platinum v4 certificates based on their scores and certification criteria and then examining these new constructions holding LEED-NCv4 Platinum certificates in terms of evaluation criteria. Therefore, the official website of the American Green Building Council (USGBC) was consulted to obtain the most up-to-date information on the LEED certification system, with the results analysed using SPSS.

2. Materials and methods

2.1. Data collection

This study discusses projects with platinum certificates from the American Green Building Council (USGBC), as certified from 2018–2023 according to the LEED-NCv4 rating system.

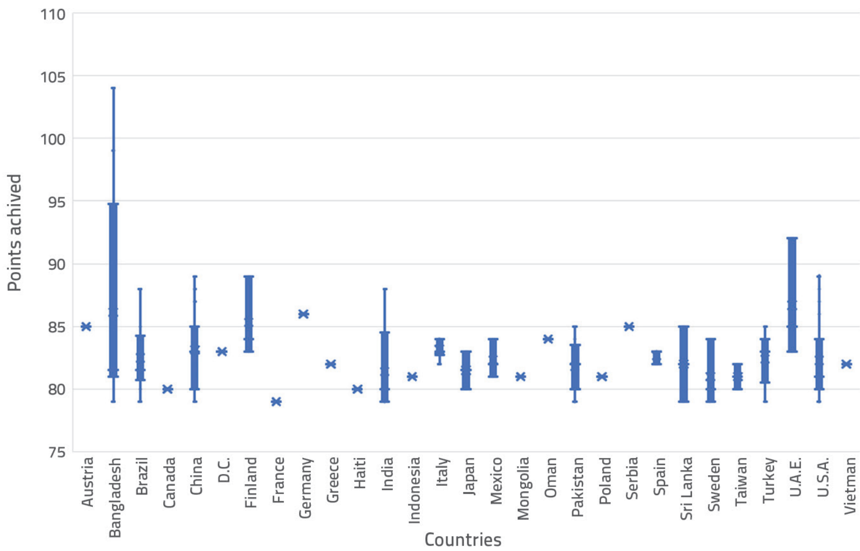

Figure 2. Distribution of certified LEED projects by country

According to the project directory, 134 projects in 29 countries were rated between 2018 and December 2023. The distribution of certified projects by country is shown in Figure 2. The scores obtained from the USGBC scorecards for the IP, LT, SS, WE, EA, MR, EQ, and IN categories were collected from an Excel database. The collected data were analysed using SPSS statistical software. The DPR Construction San Francisco ZNE building (USA) had the lowest score of 79, while the Green Textile Limited building (Bangladesh) had the highest score of 104. In general, the scores ranged from 80 to 85. While 42 projects from the USA are on this list, China follows with 15 projects. Bangladesh has eight platinum degree projects, whereas Turkiye has five.

2.2. Statistical analysis

This study combines dot plots and boxplot methods to show descriptive statistics for the LEED categories. Considering LEED data are ordinal, the median interquartile range (IQR, 25^{th}–75^{th} percentile) technique is preferred for assessing LEED-NCv4 credits [33]. The box/whisker plot shows the smallest value, the first, second, and third quartiles, and the largest value in the dataset. If the median line is below the centre, the distribution is positively skewed, if above the centre, the distribution is negatively skewed. The median line in the middle indicates that the data were normally distributed [34].

This study used inferential statistical methods to draw conclusions and estimate categories and credits based on the collected data, aiming to offer clear knowledge of the distribution and variability of LEED categories and credits using various visualisation tools, which can aid researchers and practitioners in analysing and comparing various projects in terms of their environmental effects and sustainability. First, correlations between the credit categories were analysed based on the results of 134 selected platinum-certified buildings from the 29 countries surveyed. Pearson's correlations were used to identify the variables with the greatest interdependence. Karl Pearson developed the Pearson correlation coefficient as a linear correlation coefficient to assess the relationship between two variables [35]. A straightforward correlation matrix eliminates redundant information and identifies crucial qualities [36]. This matrix visually represents the relationships among multiple variables, allowing for a more comprehensive analysis. The Pearson correlation coefficient measures the linear dependency between two random variables [37]. Historically, it was the first recognised and most popular correlation measure [38]. The Mann–Whitney U test was used to ascertain differences between the scores of platinum-certified buildings in Turkiye and other nations following the correlation analysis of these categories and credits, which is this study's primary goal. This test examines the mean difference between two independent groups from similar populations and helps determine the equality or difference between groups. Five of the 134 buildings that received the NC LEED-NCv4 Platinum certificate were in Türkiye. This test examines the mean difference between two independent groups from a similar population and determines the difference or equality between the groups [39]. This study uses descriptive and inferential statistical methods to analyse the LEED categories and credits, aiming to provide insights into the relationships between these variables and evaluate the performance of platinum-certified buildings in different countries through visualisations and statistical measurements. This research contributes to the understanding of sustainable building practices and informs future decision-making in environmental design.

3. Statistical results

The total score ranges for all the categories were different from one another. The maximum score for LT is 20, SS is 10, WE is 11, EA is 33, MR is 13, EQ is 16, and IN is 6 points. The box graph sizes of the algorithms for EQ, LT, and EA were longer than those of the other algorithms. The distance between the whiskers and box can be considered small. According to the boxplot data analysis shown in Figure 3, the widest data range of 33 was determined in the EA category, while the narrowest data range of four was determined in

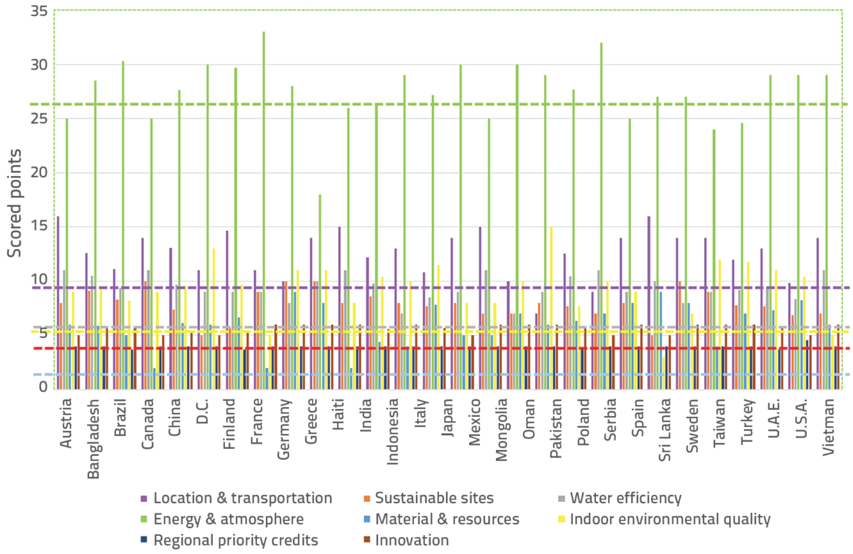

Figure 3. Boxplot/Dot plot results for LEED-NCv4 category

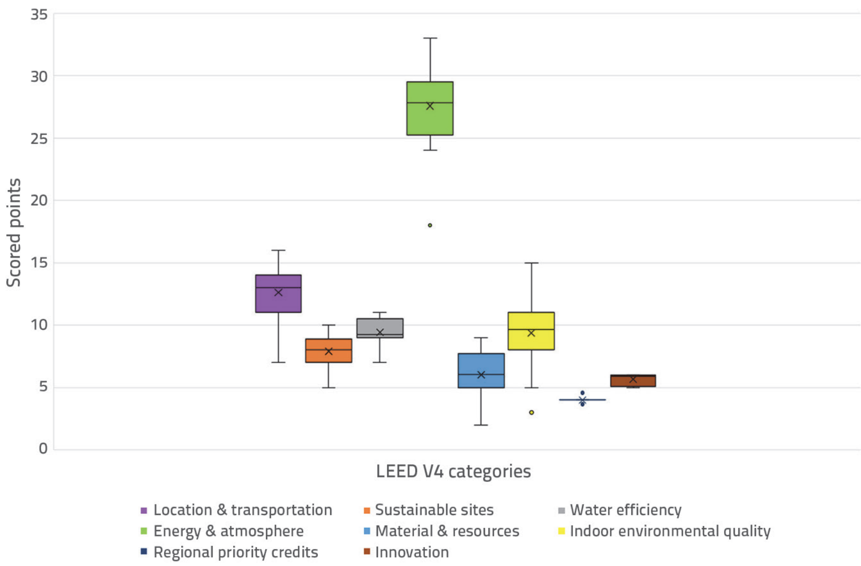

Figure 4. LEED-NCv4 categories' average points for countries

29 countries with platinum certificates. The eight coloured lines in the figure represent the average of 134 buildings. In general, results close to the average were obtained for all countries. The U.A.E. scored the highest, while Canada, the Dominican Republic, Sweden, and Haiti scored below average.

Using the SPSS tool, the credits for all categories are presented in Table 3. The binary star readings had a significance level of 0.01, whereas the one-star values had a significance level of 0.05. The data set shows a range of -1 to +1 in the correlation between the two variables. Purely positive correlations and completely negative correlations are represented by +1 and -1, respectively [40]. For the LT category, the p-value for "Sensitive land protection" and "Surrounding density and diverse uses" is 0.425, indicating a statistically significant correlation between these variables.

Moreover, the p-value for "Access to quality pass" and "Surrounding density and diverse uses" is 0.579. For the SS category, the p-value for "Open space" and "Site development-protect or restore habitat" is 0.445, and "Rainwater management" is 0.215, indicating a statistically significant relationship. For the EA category, the p-value for "Building-level energy metering" and "Enhanced commissioning" is 0.275. Moreover, in this category, "Renewable energy production" has a positive correlation with "Greenpower and carbon offsets", "Optimise energy performance", and "Enhanced refrigerant Management". In the MR category, the p-values for "environmental product declarations" and "building product disclosure and optimisation were 0.347. In addition, the p-value for "Responsible for Sourcing Raw Materials" and "Building product disclosure and optimisation" was 0.436, indicating a moderately positive correlation. In the ID category, the p-values for "Rainwater Management" and "Open space" were also positively correlated. The surrounding density and diverse use categories have the strongest link with access to quality transit credit in this table's LT category, while the quality views, daytime thermal comfort, and acoustic performance categories were moderately correlated.

the calculations made in the RP category. Considering the results of the 134 selected buildings that received platinum certification from 29 different countries, the location and transportation categories obtained a minimum of 1 point and a maximum of 16 points, respectively. The lowest and highest scores for the SS category were 2 and 10, respectively. The points in the WE category ranged from 6 to 11. The EA category distribution varied between 19 and 33, whereas that of MR ranged between 2 and 11. The EQ score ranged from 3 to 16. The RP and ID categories had only a small range of scores.

Figure 4 shows the results for the countries in all eight categories, displaying the average results for 134 buildings in

Table 3. Pearson correlation of the LEED-NCv4 credits

LT p-value	**Surrounding density and diverse uses**	**Access to quality transit**	**Reduced parking footprint**	**Green vehicles**
Sensitive land protection	0.425**	0.336**		
Access to quality transit	0.579**		0.196*	
Bicycle facilities			0.229**	0.271**
SS p-value	Open space			
Site development- protect or restore habitat	0.445**			
Rainwater management	0.215*			
WE p-value	Water metering	Indoor water use reduction		
Outdoor water use reduction	0.361**	0.503**		
EA p-value	Building-level energy metering	Greenpower and carbon offsets	Optimise energy performance	Enhanced refrigerant Management
Enhanced commissioning	0.275**			
Renewable energy production		0.350**	0.603**	0.333**
MR p-value	Environmental product declarations	Responsible for Sourcing Raw Materials		
Building product disclosure and optimisation	0.347**	0.436**		
EQ p-value	Construction IAQ Mgmt. plan	Daylight	Quality views	Interior lighting
Enhanced IAQ strategies	0.211**			
Thermal comfort		0.189*	0.244**	
Quality views		0.342**		
Acoustic performance		0.194*		
Daylight				0.212**
ID p-value	Rainwater Mgmt.	Outdoor water use reduction		
Open space	0.718**	0.672**		

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

Table 4. Mann–Whitney test results for LEED-NCv4 credits for Türkiye and other countries

Criteria / Observed parameters	High priority site	Site assessment	Optimise energy performance	Enhanced commissioning	Demand response	Thermal comfort
Mann–Whitney U-test	137.500	145.000	145.000	93.000	157.500	176.000
Asymp. Sig. (2-tailed)	0.017	0.000	0.050	0.003	0.031	0.032

Table 5. Mann–Whitney test results for LEED-NCv4 categories for Türkiye and other countries

Criteria / Observed parameters	LT	SS	WE	EA	MR	EQ	RP	ID
Mann–Whitney U test	314.500	257.500	243.000	98.500	303.500	166.000	315.000	212.500
Asymp. Sig. (2-tailed)	0.901	0.424	0.319	0.007	0.800	0.062	0.869	0.116

3.1. Statistical analysis for Türkiye

Turkiye was compared to other countries in all eight categories and credits. Using the Mann-Whitney test to evaluate the statistical differences between the eight categories and 57 credits, values with a p-value less than 0.05 were shared. Table 4 presents the relationship between Turkiye and other countries. Five out of the 57 credits yielded p-values less than or close to 0.05. The site assessment, optimised energy performance, enhanced commissioning, demand response, and thermal comfort credits were all less than 0.05, indicating a significant difference between Turkiye and other countries. These scores were particularly low in the location and transportation categories, indicating the need for better integration of sustainable transportation and site strategies. Therefore, as the number of analysed buildings increased, more sensitively significant differences were revealed between regions.

A significant difference was observed in the EA criteria for the platinum-certified buildings discussed in Turkiye when examining more than eight criteria. Turkiye's average score in the EA category was lower than that of the other countries. A result close to 0.05, with a p-value of 0.062, was obtained for the EQ criterion (Table 5). According to this table, the p-value in the EA category was 0.007, below the commonly used significance level of 0.05, indicating a significant difference between the performance of platinum-certified buildings in Turkiye and those in other countries in terms of EA criteria. Concerning the EA category, although scoring well compared with many other countries, it is below the world average, indicating the need for renewable and energy-efficient strategies. In the Indoor Environment Quality (EQ) category, a result close to 0.05 was obtained with a p-value of 0.062. Although this p-value was slightly above the significance level, it was still relatively low, indicating a potential difference. A relatively high EQ score indicates a commitment to the health and comfort of building occupants. While no significant difference exists between Turkiye's performance and that of other countries regarding EQ criteria, further research may be needed for other categories.

Recognising the flexibility inherent in the LEED certification framework is crucial because it recognises that sustainability is achievable under various approaches. LEED certification accommodates various strategies that project teams can adopt based on their circumstances, priorities, and location-specific challenges. Importantly, achieving high project ratings is not a one-size-fits-all process but a multifaceted journey that can be approached differently. This perspective should be considered when analysing the findings of this study on the performance of projects in Turkiye. The differences in scores in the different categories indicate opportunities for improvement and strategic decisions made by project teams in line with sustainability goals, resource availability, and project-specific needs. This nuanced understanding of Turkiye's sustainable building efforts highlights the potential of different strategies to contribute to broader sustainability goals.

4. Conclusion

The COVID-19 pandemic presented an opportunity for the construction industry to prioritise sustainable building and construction practices. Incorporating sustainable building principles into remediation plans addresses the pressing challenges and lays the foundation for a more sustainable, energy-efficient, and climate-resilient built environment. Therefore, certification systems worldwide are necessary to create a more sustainable world.

This study comprehensively analysed 134 LEED-NCv4 platinum-certified new construction projects in 29 countries until December 2023. The main objective of this study is to assess the performance and consistency of these projects in meeting sustainable building standards. The findings of this study are as follows.

- The LEED certification categories, including LT and SS, show inconsistent scores, with some buildings scoring as low as one point, indicating the low success rates for buildings in these categories. The RP and ID categories had narrower scores, suggesting better compliance with sustainable building standards. The EA category had the most points. However, the EQ category showed a wider range, indicating varying levels of success in these categories.
- Certain credit points in each category are significantly correlated with the other categories. The credits in the LT category for access to quality transit, reduced parking footprint, and sensitive land protection were significantly correlated. The SS category was associated with open spaces, site development, conservation, and restoration of habitat requirements. The WE category was significantly correlated with water metering, interior water usage reduction, and outdoor water use reduction. The EA category's demand response, green power and carbon offsets, increased commissioning and optimum energy performance, and credits for renewable energy generation were all correlated. The MR category is correlated with building product disclosure and optimisation, raw material sourcing, and environmental product declarations. IAQ management has a significant impact on EQ. In terms of ID, the correlation between open space and rainwater management was significant.
- Regarding the country-specific analysis, the research discovered that Turkiye ranked 11th among the countries/regions with the highest LEED certifications, totalling 556 projects. However, Turkiye scored below average in the EA category, with an average score of 24 points out of a maximum of 30, compared to the global average of 28. However, Turkiye showcased a successful performance in the EQ category, with an average score of 12 out of a maximum of 15, surpassing the global average of 9 points for platinum-certified buildings. Turkiye achieved above-average scores in the LT category, indicating commendable efforts towards sustainable transportation and location strategies. Notably, the scores in the other categories were relatively close to the mean, suggesting balanced performance in those areas.
- This study analysed the effectiveness of LEED-NCv4 platinum-certified new building projects in different regions worldwide. By assessing the strengths and weaknesses of these projects, this study provided valuable insights for developing sustainable building practices and improving LEED certification processes. Turkiye has made remarkable progress in constructing LEED-NCv4 platinum-certified buildings, showcasing its strong commitment to environmental conservation and achieving global sustainability goals in the construction industry, thus demonstrating Turkiye's proactive approach towards adopting green-building practices. In addition, this study provides insights into future platinum-certified buildings and areas that need improvement. Policymakers and industry professionals can identify these areas and take steps to achieve the targeted sustainability levels. The findings of this study revealed the need for continuous improvements in LEED certification procedures. Stakeholders must propose regulating credit requirements, provide clearer guidelines, or introduce additional incentives to promote innovative and sustainable features. Additionally, the insights of this study provide important benchmarks for LEED developers, auditors, architects, and designers working on sustainable building projects. By learning from the successful strategies highlighted in this study, individuals can implement them in their projects. This knowledge sharing contributes to collaborative efforts towards advancing sustainable building practices globally. Although Turkiye has made significant progress in sustainable building projects, this study also highlights areas requiring improvement.

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