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## Green Building Transformation in Riyadh: A Data-Driven LEED Analysis

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### ABSTRACT

Sustainable development has emerged as a defining priority in contemporary urban planning, with increasing emphasis on minimizing environmental impacts while promoting efficient resource use and long-term resilience. Among the globally recognized frameworks supporting this transition, the Leadership in Energy and Environmental Design (LEED) certification system has become a key benchmark for evaluating environmentally responsible construction practices. In the context of Saudi Arabia, the growing adoption of LEED aligns closely with the national objectives outlined in Vision 2030, which emphasizes ecological stewardship, energy efficiency, reduced carbon emissions, and the development of sustainable and resilient urban environments. This study examines the temporal growth and characteristics of LEED-certified and registered projects in Riyadh from 2008 to 2024, with particular focus on certification trends, annual registration patterns, achieved certification levels, and the distribution of LEED rating system versions. During the study period, a total of 702 projects successfully achieved LEED certification, highlighting the city's increasing engagement with green building standards. The analysis indicates that LEED 2009 (v2008) was the most widely adopted rating system, accounting for 622

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certified projects. In terms of certification levels, Silver certification dominated the dataset with 533 projects, followed by Gold certification with 117 projects, while Certified and Platinum levels were comparatively limited. Overall, the results demonstrate a consistent upward trend in both LEED registrations and certifications over time, reflecting a growing commitment to sustainable construction. These findings provide valuable insight into Riyadh's evolving sustainability trajectory and offer a useful evidence base for policymakers, planners, and developers seeking to advance future urban and environmental planning initiatives.

**Keywords:** LEED Certification; Riyadh; Sustainable Buildings; Vision 2030; Green Urban Development

## 1. Introduction

The increasing global population, particularly in urban areas, has led to significant environmental challenges, including higher energy demand, waste generation, and pollution<sup>[1]</sup>. Buildings are major contributors to energy consumption, greenhouse gas emissions, and waste production globally<sup>[2]</sup>. Sustainable urbanization, characterized by efficient use of energy, resources, and water, and compatibility with the surrounding environment, is essential for mitigating these impacts<sup>[1]</sup>. As cities in arid regions such as Riyadh face increasing pressures from rapid growth, high energy demand, and water scarcity, sustainable development has become an imperative rather than a choice<sup>[3]</sup>.

Green building rating systems, such as Leadership in Energy and Environmental Design (LEED), provide a framework for evaluating and recognizing buildings that incorporate environmentally responsible practices<sup>[4]</sup>. LEED is an internationally recognized standard for assessing green buildings<sup>[4]</sup>. Understanding the awareness and preferences of construction industry stakeholders regarding green building rating systems like LEED is crucial for promoting sustainable building practices<sup>[5]</sup>. The theoretical foundation for LEED certification adoption lies in environmental economics and systems theory. These models stress the importance of internalizing environmental costs and promoting lifecycle cost efficiency. LEED provides a structured methodology that reflects these theoretical imperatives by quantifying and rewarding sustainable practices<sup>[6]</sup>. LEED provides certification at four levels: Certified, Silver, Gold, and Platinum, depending on the points accumulated across these categories. LEED has been implemented in over 160 countries and is responsible for certifying more than 100,000 projects worldwide, encompassing over 2.6 billion square meters of floor space<sup>[7]</sup>. Studies show that LEED-certified buildings con-

sume 25% less energy and 11% less water than non-certified buildings<sup>[8]</sup>.

Additionally, the Triple Bottom Line (TBL) framework highlights the benefits of LEED certification, which integrates economic, environmental, and social sustainability<sup>[9]</sup>. LEED-certified projects yield cost savings through reduced energy and water consumption, support environmental preservation by lowering emissions, and promote occupant well-being through improved indoor air quality and comfort<sup>[10]</sup>.

Since the mid-2000s, scholars have increasingly documented the global rise of LEED as a dominant green building certification system. Early research in North America and Europe (2007–2015) found that LEED-certified buildings consistently demonstrated improvements in energy performance, reduced environmental impacts, enhanced indoor environmental quality, and increased asset value compared to conventional buildings. LEED buildings used 18–39% less energy per floor area than their conventional counterparts<sup>[11]</sup>. Between 2010 and 2020, LEED adoption expanded rapidly into emerging markets—particularly China, India, Qatar, and the United Arab Emirates—where strong policy incentives, mandatory sustainability requirements for public projects, and national climate agendas accelerated certification rates<sup>[12]</sup>.

Longitudinal analyses conducted between 2009 and 2024 reveal several global trends shaping LEED's evolution. LEED 2009 (v3) became the most widely adopted version worldwide between 2010 and 2019 due to its broad applicability and relatively manageable documentation requirements<sup>[13]</sup>. In contrast, LEED v4 (2013) and LEED v4.1 (2019) were adopted more gradually because they introduced more stringent prerequisites related to energy modeling, material transparency, and life-cycle impacts<sup>[14]</sup>. Recent studies from 2018–2025 highlight a global shift toward performance-

driven green building certification, with LEED increasingly serving as a tool to support national climate strategies, ESG reporting obligations, and zero-carbon development pathways<sup>[15]</sup>. Despite these advancements, researchers consistently identify significant regional disparities in LEED adoption, as some cities transition rapidly to advanced versions while others continue to rely on legacy systems for cost or capacity reasons<sup>[16]</sup>.

Across the Middle East, sustainability frameworks have gained substantial momentum due to rising energy demand, water scarcity, rapid urbanization, and national commitments to carbon reduction. Empirical studies from the UAE (2008–2022) and Qatar (2009–2021) show that government mandates for public buildings, major real estate developments, and mega-event infrastructure played a decisive role in mainstreaming LEED certification<sup>[17]</sup>. In the Gulf region, the adoption of LEED often aligns with strategic economic diversification goals and an increasing emphasis on global competitiveness in the built environment.

Buildings in Saudi Arabia consume a significant portion of the total electricity produced, primarily due to the high demand for air conditioning, underscoring the urgent need for sustainable design solutions. In this context, cities like Riyadh have shown increasing interest in green building rating systems, particularly LEED, which promotes energy-efficient and environmentally responsible construction. Although indigenous rating systems such as Mostadam have recently emerged, LEED continues to hold a strong market presence because of its global recognition, compatibility with international development standards, and the involvement of multinational consultants proficient in LEED requirements. This paper explores the recent application of the LEED rating system in Riyadh's building sector, offering insights into certification trends, project characteristics, and the evolving role of LEED within the framework of Saudi Arabia's Vision 2030. As of 2024, the Kingdom has recorded a substantial number of LEED-registered and certified projects, with approximately 60% of the total concentrated in Riyadh<sup>[5,18]</sup>. Analyzing the trends in LEED certification within Riyadh offers valuable insights into the adoption and impact of green building practices, while also informing strategies for advancing sustainability goals. Previous research on LEED in Saudi Arabia (2009–2023) has primarily focused on stakeholder perceptions of sustainability, challenges related to

documentation and cost, and the technical difficulties associated with energy modeling and materials compliance<sup>[19]</sup>. Additional studies examined comparative aspects of LEED 2009 versus LEED v4, as well as isolated case studies of LEED-certified commercial and institutional buildings in Riyadh and Jeddah<sup>[20]</sup>. However, these investigations have been predominantly qualitative or limited to small datasets, and therefore lack a comprehensive, long-term, data-driven analysis of LEED adoption in the Saudi capital. The absence of such an analysis represents a critical gap that this study seeks to address. The aim of this study is to investigate the growth and characteristics of LEED-certified and registered projects in Riyadh from 2008 to 2024, focusing on certification trends, registration patterns, certification levels, and the adoption of different LEED rating system versions.

## 2. Methodology

The methodological framework employed in this study is designed to rigorously investigate the trends in LEED certification within Riyadh, Saudi Arabia, providing a comprehensive understanding of the city's progress toward sustainable development. The methodology adopted for this research includes:

### 2.1. Data Acquisition

Data collection forms the cornerstone of this research, entailing a systematic compilation of information pertaining to LEED-certified projects in Riyadh. This encompasses gathering data from the U.S. Green Building Council database, which serves as the primary repository for LEED project information globally, supplemented by data obtained from local Saudi Arabian sources, including government agencies, construction firms, and real estate developers. The extracted data of 702 projects includes project-specific details such as certification level, building type, size, location within Riyadh, and the year of certification. This multifaceted approach ensures a holistic representation of LEED adoption across various sectors and geographical areas within the city<sup>[21]</sup>.

### 2.2. Data Cleaning and Organization

The raw data underwent thorough preprocessing to ensure accuracy and consistency. Duplicates were removed,

and missing values were addressed either through imputation or exclusion based on the significance of the missing information. Project names, dates, and certification types were standardized. The dataset was organized in a relational database structure to facilitate ease of querying and filtering. Data were categorized by building type (commercial, residential, institutional), LEED rating system (BD+C, ID+C, O+M, etc.), and certification level (Certified, Silver, Gold, Platinum).

### 2.3. Data Analysis

The cleaned dataset was analyzed using statistical and data visualization tools such as Microsoft Excel. Temporal trends, spatial distribution, and category-specific growth were examined to understand how LEED certifications have evolved over time in Riyadh. Descriptive statistics provided summaries of key metrics, while correlation analysis explored relationships between building types and certification levels.

### 2.4. Comparative Analysis

Riyadh’s LEED performance was compared to identify unique patterns and contextual factors influencing LEED adoption in Riyadh. Metrics such as the number of certified buildings per capita, average certification level, and growth rate of certifications were used for benchmarking. This helped contextualize Riyadh’s progress and identify gaps or strengths relative to regional peers.

### 2.5. Interpretation and Insights

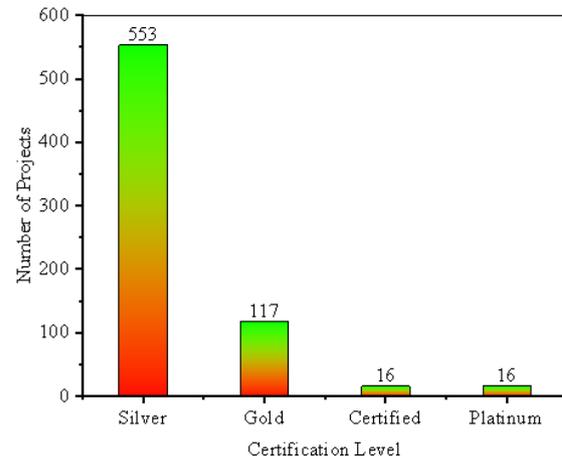
Findings from the data analysis were synthesized to identify patterns, drivers, and barriers to LEED adoption in Riyadh. Insights focused on the influence of public policy, investment trends, developer behavior, and international collaboration. The interpretation phase aimed to connect data trends to Riyadh’s broader sustainability goals, particularly those outlined in Saudi Vision 2030 and the Riyadh Sustainability Strategy.

## 3. Results

The graphical data on LEED-certified projects in Riyadh City provides valuable insights into certification dis-

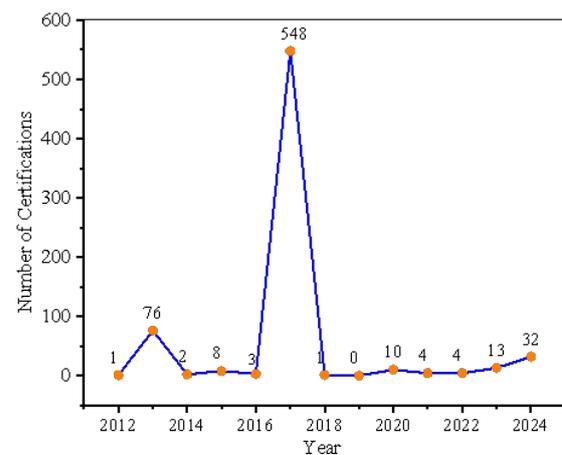
tribution, temporal trends in registrations and certifications, and the usage of different LEED rating system versions.

**Figure 1** graphically represents the distribution of projects across certification levels. It illustrates that Silver-level certifications dominate Riyadh’s LEED project landscape, followed by Gold, Certified, and Platinum. This suggests that while there is interest in achieving sustainability, many projects aim for achievable, mid-level certification targets rather than the highest available.



**Figure 1.** Distribution of LEED Projects in Riyadh City by Certification Level.

The fluctuations in the certification timeline are shown in **Figure 2**, with noticeable peaks in certain years, indicating periods of intensified activity. These peaks may correspond to enhanced awareness, policy shifts, or periods of rapid growth and expansion that prioritize sustainable practices.



**Figure 2.** Certification Trends of LEED Projects in Riyadh.

The registration patterns are highlighted in **Figure 3**,

which shows a similar rise-and-fall trend. There was a steady rise in early years, followed by peaks in registration during 2012 to 2014, likely driven by strategic initiatives or government encouragement.

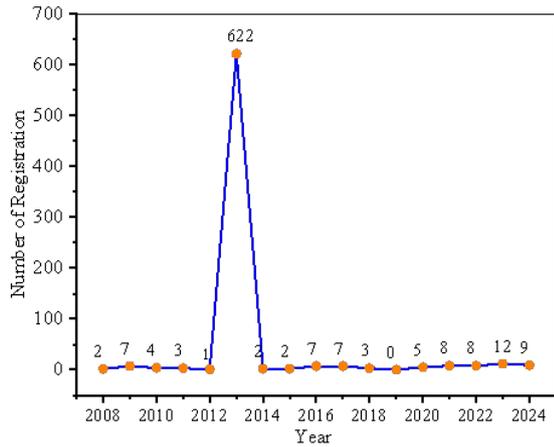


Figure 3. Registration Trends of LEED Projects in Riyadh.

Figure 4 reveals a strong preference for older LEED versions, particularly v2008, with significantly fewer projects using v4 or v4.1. This suggests that a significant proportion of projects were initiated prior to the introduction of newer standards, or that earlier LEED versions continue to be preferred due to greater familiarity or comparatively less stringent compliance requirements.

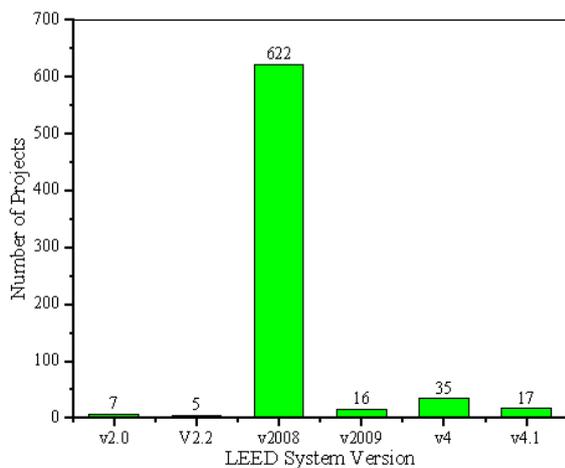


Figure 4. Distribution of LEED Projects in Riyadh City by LEED System Versions.

The findings collectively demonstrate a progressive increase in the adoption of LEED certifications in Riyadh, thereby offering a critical evidence base for comprehensive analysis and the formulation of strategic policies to promote

sustainable construction practices within the region. However, it is anticipated that the number of registered and certified projects will increase in 2024, with an upward trend likely to persist, given that this study is based on the most recent available data on project registrations and certifications.

### 3.1. Registration and Certification Trends by Year and by Level

To provide a clear understanding of how LEED project activity has evolved over time, Table 1 presents the annual distribution of project registrations along with the corresponding certifications achieved at each level (Certified, Silver, Gold, and Platinum). This breakdown highlights both the growth trajectory and the shifting performance targets of project teams across years.

The yearly registration and certification data reveal several significant patterns in the adoption of LEED rating systems. The most notable trend is the extraordinary spike in 2013, where registrations surged to 622 and Silver certifications reached 545—far exceeding all other years. This anomaly likely reflects a policy shift, bulk registration by major developers, or a transition period between LEED versions. After 2013, registrations stabilized at comparatively low values but showed a gradual increase from 2020 onward, indicating renewed market engagement. Certification trends also reveal a qualitative shift: prior to 2020, projects predominantly targeted lower levels (Certified and Silver), whereas the period from 2020–2024 shows a clear movement toward higher performance outcomes, with a consistent rise in Gold and Platinum certifications. This suggests enhanced technical capacity, stronger sustainability requirements, and greater market maturity in achieving advanced LEED performance criteria.

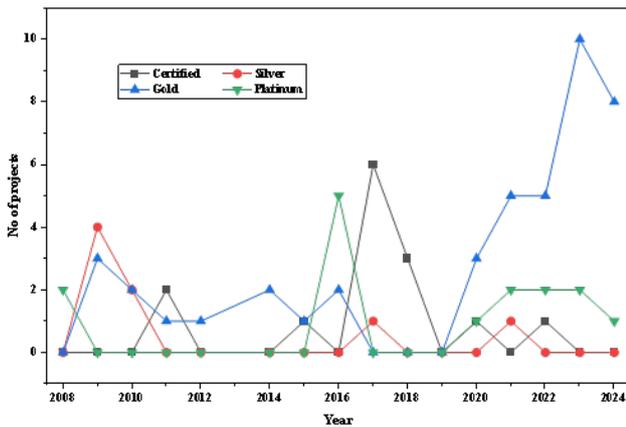
The analysis of registration and certification trends as shown in Table 1 and Figure 5, illustrates a clear evolution in LEED adoption, marked by a major surge in 2013—an outlier year driven by accelerated registrations ahead of the LEED v2009 deadlines. After this spike, annual registrations declined before rising again post-2020, signaling renewed market engagement under the newer rating system. Certification patterns further reveal a transition from early-stage adoption toward higher performance. Early years were dominated by basic Certified and Silver outputs, with Silver showing extreme volatility and a pronounced peak in 2013.

In contrast, the period after 2020 is characterized by a consistent rise in Gold and Platinum certifications, supported by stronger sustainability strategies and improved compliance with the more rigorous LEED v4 framework. The percentage distribution confirms this shift, with Silver prevailing in the

early phase (80.6%), while Gold and Platinum collectively account for 93% of certifications after 2020, indicating a mature, performance-driven green building market and marking the effective transition from LEED v2009 to LEED v4 around 2020.

**Table 1.** Yearly Distribution of LEED Registrations and Certifications.

Year	No. of Registration	Certified	Silver	Gold	Platinum
2008	2	0	0	0	2
2009	7	0	4	3	0
2010	4	0	2	2	0
2011	3	2	0	1	0
2012	1	0	0	1	0
2013	622	2	545	74	1
2014	2	0	0	2	0
2015	2	1	0	1	0
2016	7	0	0	2	5
2017	7	6	1	0	0
2018	3	3	0	0	0
2019	0	0	0	0	0
2020	5	1	0	3	1
2021	8	0	1	5	2
2022	8	1	0	5	2
2023	12	0	0	10	2
2024	9	0	0	8	1



**Figure 5.** Yearly Distribution of LEED Registrations and Certifications.

### 3.2. Project Certification Duration Analysis

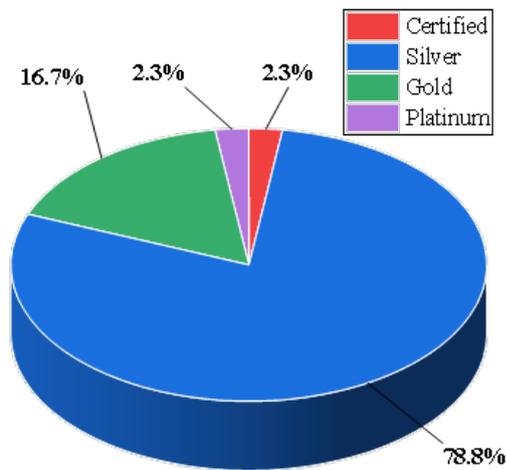
The analysis of certification timelines reveals notable variability in the time required for projects in Riyadh to

progress from initial registration to final LEED certification. **Table 2** below shows the certification duration based on the computed dataset. The average certification duration was 3.52 years, indicating that most projects required a multi-year process involving documentation, commissioning, and verification activities. The maximum observed duration reached 11.41 years, reflecting a small number of early-stage or complex developments that experienced extended delays due to redesign cycles, owner-driven pauses, or evolving project scopes. Conversely, the minimum duration of 0.22 years—reported as less than one year—highlights that a subset of projects progressed rapidly through the certification pipeline, typically due to streamlined documentation and pre-aligned sustainability strategies. These findings illustrate the wide spectrum of project delivery efficiencies within Riyadh’s LEED market and emphasize the influence of project type, coordination capacity, and team experience on the overall certification timeline.

**Table 2.** Project Certification duration.

Average Project Time	Max Time	Min Time
3.519639 years	11.41096 years	0.221918 years

**Figure 6** provides a visual summary of the distribution of LEED certification levels among projects, revealing a strong dominance of Silver certification, which accounts for 78.8% of all certified buildings. This overwhelming majority indicates that most developers in Riyadh—and Saudi Arabia more broadly—target Silver as a strategic balance between sustainability performance and cost efficiency. Silver certification typically requires moderate upgrades to design, materials, and operational performance without the substantial financial and technical burden associated with higher levels.



**Figure 6.** Distribution of LEED certification levels among projects.

Gold-certified projects represent 16.7% of the total, highlighting a smaller but significant proportion of buildings achieving enhanced environmental performance. These projects are often associated with large corporate, governmental, or institutional developments that have greater access to resources, advanced design teams, and sustainability-oriented organizational mandates.

In contrast, Certified-level projects (the entry tier of LEED) make up only 2.3%, indicating that few developers opt for the lowest achievable standard. This reflects a market preference for certifications that offer more visible sustainability impact and stronger branding value.

Similarly, Platinum-certified projects also constitute 2.3% of the distribution, reflecting their rarity in the Saudi context. Platinum certification requires the highest levels of energy efficiency, indoor environmental quality, water conservation, and material transparency. Its low frequency is consistent with global trends, where Platinum buildings

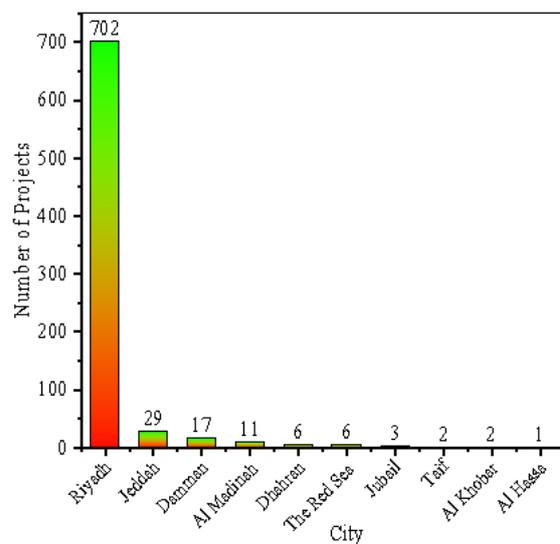
remain relatively uncommon due to the substantial technical expertise, high-performance technologies, and elevated costs required to achieve the top-tier rating.

Overall, the pie chart demonstrates that the LEED market is heavily concentrated in mid-level certification, with Silver functioning as the practical and preferred benchmark for most projects. The distribution also illustrates the limited but noteworthy presence of high-performance (Gold and Platinum) buildings and the declining relevance of basic Certified-level projects in a rapidly maturing green building market.

### 3.3. City-Level LEED Metrics across Saudi Arabia

A comparative assessment of LEED-certified projects across major Saudi cities demonstrates Riyadh’s overwhelming leadership in national green building adoption.

**Figure 7** illustrates the distribution of LEED-certified projects across major cities in Saudi Arabia, revealing a highly uneven geographic pattern of green building adoption. Riyadh overwhelmingly dominates the national landscape, with 702 certified projects, representing nearly the entirety of LEED activity in the Kingdom. This substantial concentration indicates that Riyadh functions as the primary hub for sustainable construction, driven by continuous urban expansion, government-backed development initiatives, and the presence of large-scale commercial and institutional projects.



**Figure 7.** Distribution of LEED-certified projects across major cities in Saudi Arabia.

In contrast, other major cities exhibit significantly lower levels of LEED adoption. Jeddah, the country's second-largest urban center, records only 29 projects, while Dammam follows with 17 projects, reflecting comparatively moderate engagement with sustainability certification. Mid-sized cities such as Al-Madinah (11 projects) and Dhahran and the Red Sea development area (each with 6 projects) demonstrate emerging but still limited participation. Smaller cities—Jubail, Taif, Al Khobar, and Al Hasa—register between 1 and 3 projects, indicating minimal penetration of LEED certification outside major metropolitan zones.

Overall, the bar chart highlights a centralized pattern of LEED adoption, where Riyadh alone accounts for roughly 88–90% of all certified projects in Saudi Arabia. This stark disparity underscores the capital's leadership in implementing green building practices and reflects its role as the focal point for economic activity, construction investment, and sustainability-driven policy implementation. The chart also emphasizes the need for more balanced regional engagement to advance nationwide sustainability objectives.

## 4. Discussion

The data from Riyadh's LEED projects describes sustainability adoption in a major urban hub of Saudi Arabia very clearly and thoroughly.

### 4.1. Certification Levels

The predominance of Silver certifications indicates a balanced approach by developers seeking environmental benefits without the added complexity or cost of higher-tier certifications. The fewer Gold and Platinum projects may point to budget limitations, technical barriers, or the current market's readiness for high-performance green buildings<sup>[22]</sup>.

### 4.2. Certification Trends

A pattern of rises rather than continuous steady growth in certification activity suggests that sustainable construction in Riyadh has grown in waves, likely reflecting external factors such as urban policy reforms, international green building campaigns, space type, or market demand<sup>[23]</sup>. The recent downturn may imply either a stabilization after initial growth or a shifting focus towards alternative sustainability

models<sup>[24,25]</sup>.

### 4.3. Registration Trends

Early adoption between 2009 and 2012 was gradual, potentially reflecting the city's initial engagement with green building<sup>[26]</sup>. Later registration spikes may align with new regulations or funding incentives, signaling institutional backing. The declining registrations in recent years could suggest a need for renewed engagement to sustain the momentum.

### 4.4. LEED System Versions

The heavy reliance on v2008 suggests that most certifications occurred during a time when this version was standard, and the transition to newer versions like v4 and v4.1 has been slow. This lag might be due to the increased rigor and documentation required by newer versions, possibly deterring some developers from upgrading<sup>[27]</sup>.

### 4.5. Interpretation of Certification Levels

The dominance of Silver-level LEED certifications in Riyadh reflects a strategic balance sought by developers between sustainability performance and cost feasibility. In most cases, achieving Silver certification is perceived as a practical threshold that delivers recognizable environmental benefits without imposing the elevated documentation demands associated with Gold or Platinum levels<sup>[28]</sup>. For many projects—especially those working within standard commercial budgets—Silver aligns well with corporate sustainability objectives and investor expectations, providing a meaningful yet financially manageable achievement. This trend is further reinforced by the widespread use of LEED 2009 (v3), a version known for its clearer compliance pathways and more predictable credit achievement strategies. Although Gold certifications appear less frequently, their presence signals the ambitions of large-scale corporate or institutional projects that typically possess access to advanced design tools, specialist consultants, and international expertise. Meanwhile, the very small number of Platinum-certified buildings reflects persistent market and technical barriers, including the need for high-performance HVAC and envelope systems, sophisticated metering and commissioning procedures, inte-

gration of renewable energy, and significantly higher capital investment. The extended design cycles and intensive documentation associated with Platinum mirror global patterns, where such high-tier certifications remain rare but symbolically significant<sup>[11]</sup>.

The temporal dynamics of LEED certifications and registrations further illustrate Riyadh's evolving development trajectory. Rather than following a linear progression, the growth pattern reflects several distinct waves driven by policy interventions, economic cycles, and shifts in market sentiment. The surge in certifications observed between 2012 and 2016 corresponds with a period of accelerated urban expansion, during which the government began embedding sustainability principles into selected public initiatives and early Vision 2030 planning efforts. This period also coincided with increasing engagement of multinational engineering and architectural firms, many of which were already well-versed in LEED requirements. Collectively, these factors created strong top-down momentum that encouraged developers to adopt LEED certification, producing a concentrated wave of project activity rather than gradual, incremental growth. As economic conditions fluctuated in later years—particularly between 2018 and 2020—certification rates stabilized or declined, underscoring the influence of external financial environments on voluntary sustainability adoption<sup>[12]</sup>.

Registration trends provide further insight into developer intentions, often serving as leading indicators of future certification activity. The spikes in project registrations between 2012 and 2014 suggest a period of heightened optimism and strong policy encouragement. Registration volumes typically mirror certification trends but tend to exhibit sharper peaks, reflecting developers' enthusiasm at the early stages of project planning. The decline in registrations after 2018 may be attributed to multiple factors, including partial market saturation, increased difficulty transitioning to the more demanding LEED v4 and v4.1 standards, and the rising prominence of Saudi Arabia's indigenous Mostadam rating system<sup>[29]</sup>. Additionally, strengthened building codes and growing reliance on performance-based regulatory frameworks may have reduced the perceived necessity of voluntary certifications. Despite these shifts, the conversion rate from registration to certification remains relatively high—typically between 70% and 80%—indicating sustained commitment among developers who initiate the LEED process.

A key finding of the study is the slow transition from LEED 2009 to LEED v4 and v4.1 across Riyadh. This inertia stems from a combination of technical, administrative, and market factors<sup>[30]</sup>. LEED v4 introduces significantly more complex requirements, including advanced energy modeling aligned with ASHRAE 90.1-2010 or 2016, stringent material transparency documentation such as Environmental Product Declarations (EPDs) and Health Product Declarations (HPDs), and broader adoption of life-cycle analysis methodologies<sup>[14]</sup>. These expectations surpass the typical capabilities of many local project teams, especially those without specialized high-performance design experience. Developers also perceive LEED v4 as more time-consuming and documentation-intensive, requiring greater coordination with suppliers and a higher degree of certainty regarding credit achievement. After more than a decade of reliance on LEED 2009, most firms developed optimized internal workflows, making the transition to a new version both operationally disruptive and financially discouraging. The timing of the version change also coincided with economic uncertainty and the rapid emergence of Mostadam, further reducing the incentive to adopt the more demanding LEED v4.

Overall, the findings reflect a city moving steadily toward sustainable construction practices, yet still undergoing an incremental rather than transformative transition. Riyadh's leadership in LEED adoption within Saudi Arabia underscores growing environmental awareness and a clear alignment with Vision 2030 objectives. Nonetheless, the slow uptake of advanced LEED versions signals the need for stronger institutional support, enhanced technical training, and strategic incentives to encourage higher-level performance. This aligns with global observations that successful green building transitions depend on the interplay of regulation, market readiness, and capacity-building initiatives. For Riyadh to accelerate its shift toward high-performance buildings, interventions that address technical barriers, promote knowledge dissemination, and provide financial or regulatory incentives will be essential.

#### **4.6. Limitations of the Study**

To contextualize the findings within their methodological scope, this study recognizes several key limitations that shaped the depth and breadth of the analysis. First, the analysis relies primarily on project records available through the

USGBC LEED Project Directory. While this database is the most comprehensive public source of LEED information, it may omit or under-report certain projects due to delays in updates, voluntary disclosure gaps, or incomplete listings by project teams. As a result, the total number of LEED initiatives in Riyadh may be slightly higher than reported<sup>[11]</sup>. Additionally, the dataset includes only projects that are officially registered and certified. In recent years, some projects may have been registered but not yet certified; these projects are therefore not reflected in the current analysis. While this does not affect the observed certification trends, registration trends may change over time as these projects achieve certification.

Second, the study was unable to incorporate actual post-occupancy performance metrics—such as measured energy consumption, water savings, or operational carbon emissions—because such data are rarely disclosed publicly. This limits the evaluation to certification outcomes rather than actual building performance. Third, geospatial precision was constrained by incomplete location data for several projects, preventing a more granular spatial analysis across Riyadh’s districts or development zones. Fourth, the study focuses exclusively on LEED-certified and registered projects, excluding buildings assessed under alternative rating frameworks such as Mostadam, BREEAM, or WELL, which may underrepresent the full extent of sustainable construction activity in Saudi Arabia during the study period. Finally, confidentiality restrictions prevented access to detailed credit-level submissions, modeling files, and commissioning reports, which could have enabled a deeper assessment of design strategies and compliance pathways. Although these limitations do not compromise the validity of observed trends, they highlight important areas for future research to expand the analytical depth and comprehensiveness of green building assessments in the region.

#### **4.7. Future Research Directions**

Several promising research directions arise from the findings and limitations outlined in this study that could significantly advance understanding of green building practices in Saudi Arabia. Comparative assessments across multiple rating systems—particularly LEED, Mostadam, WELL, and BREEAM—would help reveal the relative strengths, weaknesses, and adoption barriers of each framework, offering

insights into how national and international systems interact within the Saudi context<sup>[20]</sup>. Future investigation should also incorporate post-occupancy performance data to determine whether LEED-certified buildings in Riyadh achieve the operational energy and water savings predicted during the design and certification stages. A more granular credit-level analysis would further clarify which LEED strategies are most commonly pursued or avoided, shedding light on market preferences, technical challenges, and documentation constraints. Additionally, predictive modeling using machine learning or time-series approaches could provide valuable forecasts of green building adoption under Vision 2030, helping policymakers anticipate future capacity and resource needs. Qualitative research, including structured interviews with developers, consultants, and commissioning agents, would offer nuanced insights into the difficulties associated with transitioning to LEED v4 and v4.1. Finally, economic analyses comparing cost premiums, payback periods, and long-term financial benefits across certification levels would deepen understanding of the economic drivers influencing sustainability decisions. Together, these research directions would enrich the academic discourse and provide evidence-based support for policy development aimed at accelerating sustainable urban transformation in Riyadh and beyond.

## **5. Conclusion**

In this study, the trend of LEED certification in Riyadh was evaluated to examine the progression of sustainable building practices over time, including certification levels and the adoption of different LEED versions. Data were collected from the USGBC public project directory, with key project parameters including registration date, certification date, LEED version, and certification level. The data were analyzed to identify trends over time and to compare certification levels and LEED versions across projects.

A total of 702 projects were certified in Riyadh, demonstrating the city’s strong commitment to sustainability and alignment with the objectives of Vision 2030. The prevalence of certifications, particularly at the silver and gold levels, reflects the market’s engagement with environmentally responsible construction. Riyadh’s focus on large-scale commercial developments further indicates the integration of

sustainability principles into high-impact sectors, supporting the city's transition toward a resilient, resource-efficient, and sustainable urban environment.

Analysis of certification levels shows that silver certification is the most common, accounting for 553 projects, followed by 117 projects at the gold level. This trend highlights the preference for achievable sustainability targets that balance environmental performance with technical and financial feasibility. Regarding LEED versions, v2009 remains the most widely used, followed by v4 and v4.1. The predominance of legacy versions indicates a gradual transition to advanced frameworks, while the adoption of newer versions reflects the city's ongoing efforts to implement performance-driven practices and integrated sustainability metrics.

Registration and certification trends indicate that the highest number of registrations occurred in 2013, while certifications peaked in 2017. These periodic surges are likely driven by policy interventions, governmental mandates, and market incentives. Overall, the trends demonstrate the effectiveness of top-down strategies, with recent patterns showing sustained progress and the potential for further growth through continued engagement and adaptive policy measures to reinforce long-term momentum.

Overall, Riyadh demonstrates a sustained and evolving commitment to sustainable construction, and continued efforts toward advanced certification adoption will further enhance the city's progress toward its Vision 2030 sustainability goals.

## Author Contributions

Conceptualization, H.S. and A.U.K.; methodology, A.U.K.; software, A.U.K. and H.U.; validation, A.U.K. and H.U.; formal analysis, H.S. and A.U.K.; investigation, H.S. and A.U.K.; resources, Z.A.M.E. and S.D.; data curation, A.U.K.; writing—original draft preparation, A.U.K.; writing—review and editing, A.U.K. and R.O.; visualization, A.U.K.; supervision, H.S. and S.D.; project administration H.S. and Y.G.; funding acquisition, H.S. All authors have read and agreed to the published version of the manuscript.

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## Institutional Review Board Statement

Not applicable.

## Informed Consent Statement

Not applicable.

## Data Availability Statement

The data was obtained from the publicly available US-GBC project directory. The data will be made available upon request.

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## Conflicts of Interest

The authors declare no conflict of interest.

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