Bibliometric Analysis of Sustainable Architecture and Innovative Materials in Multifamily Buildings in Latin America (2021-2024)

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Abstract– This study conducts a bibliometric analysis of sustainable architecture and innovative materials in multifamily housing in Latin America, examining research trends from 2021 to 2024 based on publications indexed in Scopus and Web of Science. The findings reveal a growing body of research, with Brazil, Chile, and Ecuador emerging as primary contributors, while Spain and Portugal play a key role in international collaborations. The study identifies central research themes, such as "social housing," "circular economy," "energy efficiency," and "construction industry," underscoring the increasing focus on sustainability and resource efficiency in the built environment. Emerging topics, including "modular construction" and "embodied carbon," highlight the shift toward innovative low-impact construction strategies. The thematic mapping categorizes research areas into established, emerging, and niche domains, offering insights into the evolution of sustainable building practices in the region. The results indicate a progressive integration of circular economy principles and energy-efficient strategies, although barriers remain in regulatory adaptation and large-scale implementation.

Keywords: Sustainable Architecture, Social Housing, Circular Economy, Energy Efficiency, Innovative Materials.

I. Introduction

The environmental impact of the construction industry has gained increasing relevance in Latin America, where rapid urban development and rising housing demand have driven the sector's accelerated expansión [1-8]. However, this growth has placed significant pressure on natural resources, as the construction sector accounts for a substantial share of energy consumption and greenhouse gas emissions [9-14]. In response to these challenges, the pursuit of sustainable solutions has led to growing interest in sustainable architecture and the use of innovative materials aimed at optimizing the environmental performance of buildings [15-21].

Sustainable architecture has emerged as a key strategy to mitigate the environmental impact of buildings, promoting construction practices that integrate energy efficiency, bioclimatic design, and low-impact materials. Alternative materials such as bamboo, bioconcrete, and recycled components have demonstrated their potential to reduce dependence on non-renewable resources and enhance the thermal efficiency of buildings [22-28]. However, despite the growing interest in these strategies, their adoption in Latin America continues to face structural challenges, including the lack of specific regulations, limited incentives for innovation, and resistance within the construction sector to modifying traditional methods [29-30].

Beyond environmental concerns, the region is also grappling with a persistent housing crisis. A significant proportion of the population still lives in precarious conditions, underscoring the need for construction solutions that are not only sustainable but also affordable and scalable [31-37]. The implementation of passive design strategies and alternative materials could substantially reduce construction costs and improve living conditions in vulnerable communities. However, the lack of technical knowledge and limited sustainability training within the sector remain key barriers to the widespread adoption of these practices [38-44].

In this context, scientific research on sustainable architecture and innovative materials in multifamily housing has gained momentum in recent years. Analyzing the evolution of this research output in Latin America is crucial to identifying trends, knowledge gaps, and opportunities for future studies.

Therefore, this study conducts a bibliometric and content analysis of academic literature on sustainable architecture and innovative materials in multifamily buildings in Latin America for the period 2021–2024. By examining publications indexed in Scopus and Web of Science, this study aims to identify major research lines, leading authors and institutions, and the predominant thematic approaches in recent literature. Additionally, it explores international collaboration patterns and emerging trends in the development and application of sustainable materials. The insights derived from this study will not only provide a comprehensive understanding of the current research landscape but will also serve as a foundation for formulating strategies that promote the adoption of sustainable technologies in the region, aligning with the environmental, economic, and social challenges of Latin America.

II. METHODOLOGY

This study applies a PRISMA-guided bibliometric approach to assess the scientific output on sustainable architecture and innovative materials in multifamily buildings in Latin America from 2021 to 2024. To achieve this, publications were retrieved from Scopus and Web of Science (WoS) to assemble a comprehensive overview of the field.

To refine the search, a strategy was defined based on specific terms covering various dimensions of sustainable architecture and innovative construction materials. The selected concepts included sustainable design and energy efficiency-related terms such as *"sustainable architecture"*, *"green building"*, *"climate-responsive design"*, *"zero-energy buildings"*, and *"energy-efficient buildings"*. Additionally, terms related to innovative materials, such as *"bamboo construction"*, *"bioconcrete"*, *"low-carbon materials"*, *"recycled material"*, and *"circular economy"*, were incorporated, along with specific concepts concerning multifamily buildings, including *"multifamily housing"*, *"modular construction"*, *"social housing"*, and *"high-density housing"*. These terms were applied exclusively to titles, abstracts, and keywords in the retrieved documents to ensure the selection accurately reflected the current state of research in this field (Table 1).

To build a robust dataset, we first included publications published in English (the only language available in our retrieval) between 2021 and 2024 that feature at least one institutional affiliation in a Latin American country (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panamá, Paraguay, Perú, Dominican Republic, Uruguay, and Venezuela) and are classified as Article, Review, or Proceeding Paper—ensuring each record is rooted in the Latin American research context. We then excluded any records labeled "Early Access," "Editorial Material," "Correction," "Data Paper," or "Retracted Publication," focusing our analysis exclusively on rigorously vetted scholarly work (see Figure 1 and Table 1).

The initial search in Scopus and WoS retrieved a total of 43 documents, with 29 from Scopus and 14 from WoS. Using Bibliometrix (RStudio), three duplicate documents were removed, resulting in a final sample of 40 unique records.

To further refine the dataset, a content review was conducted to assess the alignment of the studies with the objectives of this analysis. As a result, where 16 were excluded at title/abstract for lacking a Latin American case focus or misaligned scope. During the Eligibility stage, the full text of 24 articles was assessed (no further exclusions), and these 24 studies were Included in the bibliometric analysis. This exclusion was based on five key criteria (see Table 1). First, studies written by Latin American authors or related to sustainability but lacking case studies, field tests, or implementation strategies in Latin America were discarded due to their limited applicability to the regional context. Additionally, articles that addressed sustainability in buildings but focused on offices, public infrastructure, or single-family housing—without specifically examining their impact on multifamily construction—were excluded.

Another group of documents was removed due to their theoretical nature without empirical validation. While these studies provide a valuable conceptual foundation, they do not directly contribute to the analysis of applied innovations in multifamily buildings in Latin America. Similarly, some articles explored sustainable materials but did not demonstrate their integration into multifamily construction systems, limiting their relevance within the scope of this research.

Finally, studies focusing exclusively on energy efficiency strategies without addressing material innovations or construction processes were excluded. Since the purpose of this analysis is to understand the intersection between energy efficiency and new materials in multifamily buildings, these works were not considered in the final sample.

The bibliometric analysis was conducted in two main phases. In the first phase, relevant documents were identified and selected based on the criteria outlined in Figure 1 and Table 1. Metadata coherence and normalization were ensured by unifying author names, institutions, and key terms to guarantee accuracy in data processing. In the second phase, the Bibliometrix package (RStudio) and VOSviewer (version 1.6.20) were used to analyze co-authorship networks, keyword co-occurrence maps, and citation impact within the scientific literature.

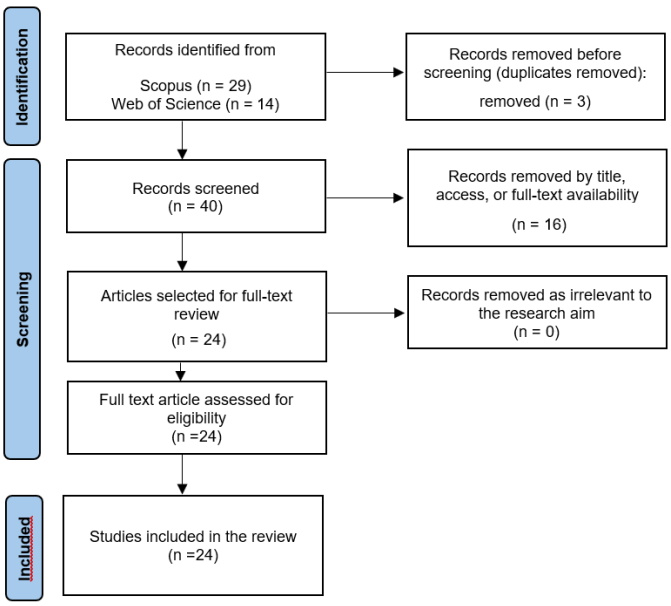


Figure 1. Flowchart describing the methodology used to select and filter documents on sustainable architecture and innovative materials in multifamily buildings in Latin America.

TABLE 1. COMPONENTS OF THE BIBLIOMETRIC SEARCH STRATEGY

Component	Descripción	Términos/Operadores
Search Fields	Specific areas searched within the database	Title, Abstract, Keywords (TITLE-ABS-KEY (Scopus) / TS (WoS))
Keyword Group 1	Sustainable architecture and energy efficiency	"sustainable architecture", "green building", "eco-friendly design", "climate-responsive design", "zero-energy buildings", "energy-efficient buildings", "passive design", "life cycle assessment"
Keyword Group 2	Innovative construction materials	"bamboo construction", "bioconcrete", "low-carbon materials", "recycled material", "eco-materials", "circular economy"
Keyword Group 3	Multifamily housing	"multifamily housing", "apartment building", "modular construction", "social housing", "urban housing", "high-density housing"
Boolean Operators	Connectors for combining concepts	OR (within each group), AND (between groups)
Inclusion Criteria	Parameters for selecting relevant documents	Publications in English with institutional affiliations in Latin American countries (Argentina, Peru, Brazil, Ecuador, Colombia, Mexico, Chile and Bolivia). Publication period: 2015–2024.
Exclusion Criteria	Documents not relevant to the study	"Early Access", "Editorial Material","Correction", "Data Paper", "Retracted Publication"
Filters	Criteria for refining the search	Document type: "Article", "Review","Proceeding Paper"

III. ANALYSIS AND DISCUSSION

A. *Distribution of Scientific Production by Country*.

Figure 2 illustrates the distribution of scientific publications on sustainable architecture and innovative materials in multifamily buildings in Latin America, distinguishing between single-country publications (SCP) and those resulting from international collaborations (MCP). Brazil leads in scientific production with nine publications, accounting for 37.5% of the total. Of these, six correspond to national publications, while three involve international collaboration, reflecting an internationalization rate of 33.3%. This leadership may be linked to the consolidation of academic networks in sustainability and the country's growing investment in research.

Chile ranks second with five publications (20.8% of the total), of which four are SCP and one is MCP, representing a 20% international collaboration rate. This suggests that while Chile maintains significant national scientific production, its integration into international networks is lower compared to Brazil.

Colombia, with three publications (12.5%), exhibits exclusively national scientific production (100% SCP, 0% MCP). This pattern could be related to limitations in international funding or a stronger focus on addressing local issues in sustainable architecture. A similar trend is observed in Argentina and Peru, each with one publication (4.2% of the total), both entirely national, with no international collaborations.

On the other hand, Ecuador and Spain show a different pattern. Although each has only two publications (8.3% of the total), both exhibit a 50% rate of international collaboration. This high MCP percentage suggests a greater openness to cooperation with foreign institutions, potentially enhancing the visibility and impact of their research in global literature.

Overall, Figure 2 reveals that while Brazil and Chile lead in terms of publication volume, international collaboration levels vary significantly among countries. Ecuador and Spain stand out for their high MCP percentage, indicating a well-established internationalization strategy. In contrast, the absence of MCP in countries such as Colombia, Argentina, and Peru suggests lower integration into international research networks, highlighting an opportunity to enhance scientific cooperation and access global funding for sustainability and innovative materials research in multifamily buildings.

Figure 2: Distribution of Scientific Publications by Country

Figure 3 illustrates the global distribution of scientific production on sustainable architecture and innovative materials in multifamily buildings. A strong concentration of publications is observed in Latin America, with Brazil, Chile, and Ecuador emerging as the primary contributors. Brazil leads with 14 publications, followed by Chile with 9 and Ecuador with 8, reflecting a growing research ecosystem and increasing attention to sustainable construction solutions.

Argentina, Colombia, and Peru report a lower number of publications (ranging between three and four), which may indicate differences in resource availability and the level of consolidation of their scientific communities in this field. Nevertheless, their presence in this analysis suggests a rising interest in developing sustainable construction strategies across the region.

At an international level, Portugal, Spain, and Germany stand out for their contributions to this research area, suggesting collaborative ties with Latin America, possibly through joint projects and research networks. In contrast, countries with high scientific production in other fields—such as China, the United States, and the United Kingdom—show less representation in this analysis, which may indicate a more localized focus on sustainable architecture research within their respective contexts.

The distribution observed in Figure 3 highlights the need to strengthen scientific cooperation between countries. Nations with higher research output, such as Brazil and Chile, are well-positioned to facilitate Latin America's integration into global collaboration networks. By promoting knowledge exchange and fostering the development of innovative building solutions, these countries can play a key role in advancing sustainability in the construction sector across the region.

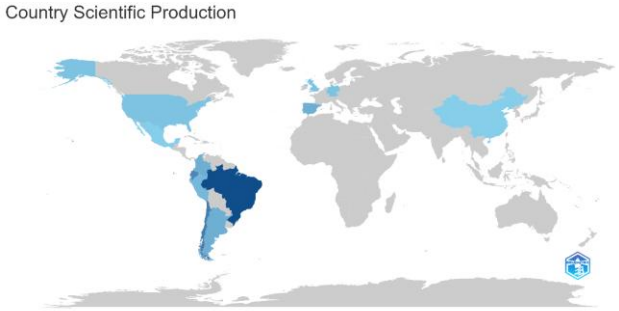


Figure 3: Country Scientific Production.

B. *Most Relevant Keywords.*

Figure 4 presents a network map summarizing the most significant concepts in the analyzed literature, providing a clear perspective on current research trends in sustainable architecture and innovative materials in multifamily buildings. This analysis helps identify the evolution of key topics and suggests new directions within the field.

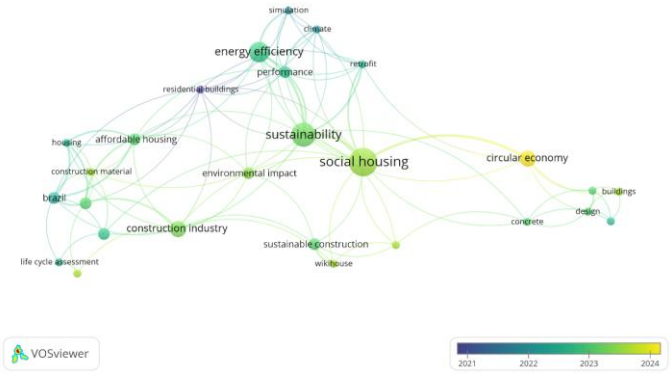
The term "social housing" is positioned at the core of the map, reflecting its central role in sustainability research for buildings. Its close association with "sustainability" and "energy efficiency" underscores the growing concern for improving energy performance in social housing. Additionally, concepts such as "performance", "retrofit", and "simulation" suggest that recent studies have focused on assessing and optimizing building performance through modernization strategies and energy modeling.

A notable aspect of the analysis is the presence of "circular economy", which is directly linked to "concrete" and "design". This connection highlights the increasing interest in reducing the environmental impact of construction by reusing materials and implementing efficient design practices. These findings reinforce the importance of adopting approaches that minimize waste and promote the sustainable use of resources.

Furthermore, the relationship between "construction industry", "affordable housing", and "construction material" suggests that academic discussions not only address the technical feasibility of sustainable architecture but also its accessibility and applicability within the real estate sector. The mention of "Brazil" in the analysis indicates that this country plays a prominent role in sustainable construction research in Latin America, which may be linked to the need for innovative solutions to meet housing demand in a sustainable manner.

The network visualization also incorporates a temporal gradient, allowing for the observation of research topic evolution. Concepts such as "circular economy" and "design" appear in more recent shades, indicating a growing interest in these areas. Meanwhile, terms like "energy efficiency" and "social housing" have maintained a consistent presence, solidifying their status as foundational elements in the scientific literature on sustainable buildings.

Figure 4: Thematic Network Visualization of Keywords.



C. *Authors and Their Collaborative Networks.*

Figure 5 illustrates the collaboration landscape among researchers in the field of sustainable architecture and innovative materials in multifamily buildings. Through the network map, key contributors to scientific production and the intensity of their academic interactions are identified.

The most prominent authors in the network, such as "Najjar, M.K.", "Alexandre, J.", and "Cecchin, D.", stand out either for their high volume of publications or their pivotal role in building collaborative research networks. Their central positioning suggests active participation in knowledge generation and strong connections with other researchers, fostering the exchange of ideas within the discipline.

The density and thickness of the lines linking the nodes reflect the strength of academic relationships. Notably, the group surrounding "Najjar, M.K." exhibits a highly interconnected structure, indicating recurrent collaborations with other experts in the field. Similarly, authors such as "da Silva, F.C." and "Monteiro, S.N." maintain a well-established network, suggesting the presence of specialized research communities within the domain of sustainable construction.

The network map also incorporates a temporal dimension through a color gradient, illustrating the evolution of scientific output between 2021 and 2024. Nodes in cooler tones correspond to researchers with contributions in the early years of the period, whereas warmer colors, associated with authors like "Silva, L.P.P." and "Vasco, D.A.", indicate more recent activity in the field. This distribution helps identify emerging trends and visualize which researchers have gained prominence in recent years.

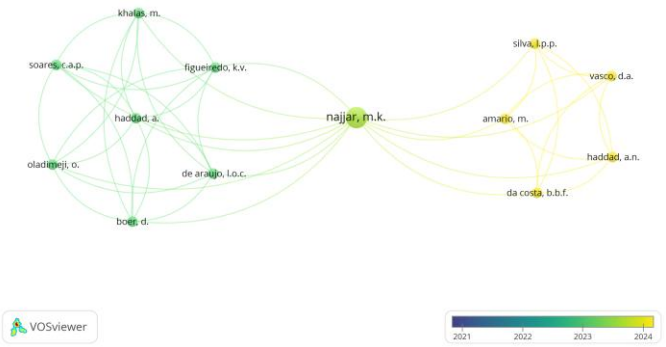


Figure 5: Map of authors with the greatest scientific production and their collaborative networks.

D. Thematic Map.

The analysis of the main research lines in sustainable architecture and innovative materials for multifamily buildings is represented in the Thematic Map (Figure 6). This diagram classifies research topics based on their level of development (density) and their relevance within the field (centrality), organizing them into four distinct quadrants.

In the upper left quadrant, niche topics such as "modular construction", "energy efficiency", "construction method", and "cycle assessment" are identified. These topics exhibit a high level of development, indicating a well-established knowledge base, but with weaker connections to the core of the research field. Their specialization suggests that they are areas of interest for specific scientific communities, with concrete applications in material optimization and energy efficiency.

The upper right quadrant contains driving themes, including "social housing", "circular economy", "construction process", and "systematic literature". Their high density and centrality position them as key elements in the advancement of the field. These themes not only have a strong research foundation but also play a crucial role in shaping sustainable strategies for multifamily housing development.

In the lower right quadrant, basic themes encompass concepts such as "construction industry", "housing deficit", "real estate", and "construction practices". Their positioning indicates that they are fundamental to research on sustainable construction, though they show a lower degree of development compared to driving themes. This suggests that they remain active areas of study, offering opportunities for new approaches and methodological advancements.

Finally, in the lower left quadrant, emerging or declining themes include "moisture content", "affordable housing", "embodied carbon", and "energy performance". Their low centrality and density may reflect evolving trends within the field or, in some cases, a decline in research interest. These topics could present new opportunities for future studies or indicate areas that have been overshadowed by more current research directions.

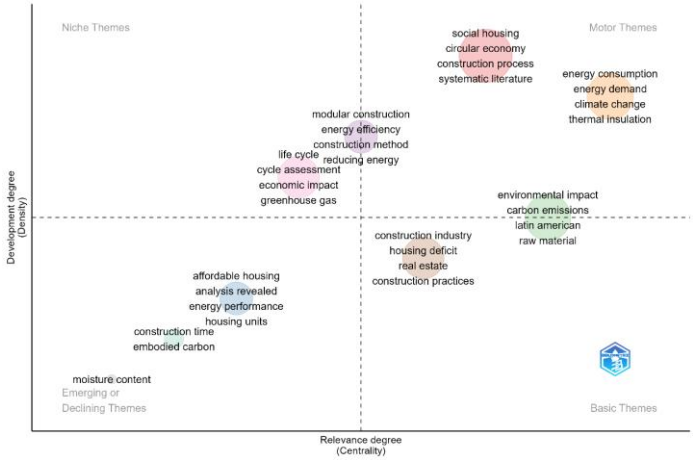


Figure 6: Strategic Diagram of Research Themes.

IV. CONCLUSIONS

The bibliometric analysis of sustainable architecture and innovative materials in multifamily buildings in Latin America (2021-2024) has revealed sustained growth in scientific production and the expansion of academic collaboration networks. The findings indicate that Brazil and Chile lead research in the region, with notable participation from researchers in Spain and Portugal in international collaborations.

The keyword analysis has identified key research topics, highlighting terms such as "social housing", "circular economy", "energy efficiency", and "sustainability", which reflect the growing interest in integrating energy efficiency strategies and innovative materials into multifamily housing construction. Additionally, emerging concepts like "modular construction" and "embodied carbon" suggest an evolution toward more sustainable approaches in the industry.

The co-authorship network study identified Najjar, M.K., Alexandre, J., and Cecchin, D. as key contributors to scientific production, with increasing involvement from emerging researchers such as Silva, L.P.P. and Vasco, D.A. This trend indicates greater diversification within the academic community.

The thematic mapping has helped categorize the primary research trends. Driving themes such as "social housing" and "circular economy" have solidified their role as pillars in the field's development, while basic themes like "construction industry" and "housing deficit" remain essential but present

opportunities for further exploration. Likewise, emerging topics such as "moisture content" and "embodied carbon" open new lines of research focused on optimizing the environmental performance of construction materials.

In summary, the findings suggest that research on sustainable architecture and innovative materials in multifamily buildings is undergoing a phase of expansion, characterized by increased international collaboration and methodological diversification. However, challenges remain in integrating these advancements into building regulations and public policies. Strengthening academic networks, promoting the adoption of low-impact materials, and improving the integration of sustainable strategies into urban development will be key to the future of sustainability in the Latin American construction sector.

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