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INTEGRATING SUSTAINABILITY IN FURNITURE DESIGN: A HOLISTIC ANALYSIS OF MATERIALS, MANUFACTURING PROCESSES, AND CIRCULAR ECONOMY

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ABSTRACT

Objective: To examine the integration of sustainability in furniture design, focusing on material innovation, manufacturing process efficiency, and circular economy.

Theoretical Framework: The study draws on current industry practices and challenges, emphasizing adaptive strategies and the role of digital technology in sustainability.

Method: The research involved an in-depth analysis of academic literature, assessing sustainable practices and trends in furniture design.

Results and Conclusion: Findings highlight the importance of conscious resource utilization, development of recyclable furniture, and preservation of natural resources for economic competitiveness and social responsibility.

Implications: The study provides significant contributions to socio-environmental management, promoting sustainable design practices**.**

Originality/Value: The research contributes to the advancement of knowledge in sustainable furniture design, emphasizing the importance of circular economy.

Keywords: Sustainable Design, Digital Technology, Resource Management, Economic Competitiveness, Social Responsibility.

INTEGRAÇÃO DA SUSTENTABILIDADE NO DESIGN DE MÓVEIS: UMA ANÁLISE HOLÍSTICA DE MATERIAIS, PROCESSOS DE FABRICAÇÃO E ECONOMIA CIRCULAR

RESUMO

Objetivo: Examinar a integração da sustentabilidade no design de móveis, enfocando inovação em materiais, eficiência de processos de fabricação e economia circular.

Referencial Teórico: O estudo baseia-se em práticas atuais e desafios da indústria, com ênfase em estratégias adaptativas e papel da tecnologia digital na sustentabilidade.

Método: A pesquisa envolveu análise detalhada de literatura acadêmica, avaliando práticas sustentáveis e tendências em design de móveis.

Resultados e Conclusão: Os achados destacam a importância da utilização consciente de recursos, desenvolvimento de móveis recicláveis e preservação de recursos naturais para manter a competitividade econômica e responsabilidade social.

Implicações: O estudo oferece contribuições significativas para a gestão socioambiental, promovendo práticas de design sustentáveis.

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Originalidade/Valor: A pesquisa contribui para o avanço do conhecimento em design sustentável de móveis, enfatizando a importância da economia circular.

Palavras-chave: Design Sustentável, Tecnologia Digital, Gestão de Recursos, Competitividade Econômica, Responsabilidade Social.

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1 INTRODUCTION

Sustainable Furniture Design has emerged as a key discipline in the field of industrial design, responding to contemporary environmental and social challenges. In a world increasingly aware of issues related to environmental degradation and the depletion of natural resources, the role of the furniture designer has evolved beyond the simple act of aesthetic creation. Now he embraces the responsibility of shaping a more sustainable future through careful choice of materials, processes and concepts that minimize negative impact on the planet and promote users' quality of life (Desing, 2021; Bosch et al., 2017).

This literature review seeks to address these principles in a detailed and reasoned manner, providing a comprehensive overview of the state of the art of Sustainable Furniture Design. This interdisciplinary field combines knowledge of design, materials science, engineering and sustainability, creating a synergy that results in products that are aesthetically appealing and ecologically responsible and socially beneficial (Kuzman, 2020; Berg, 2022).

In this review, we will explore a number of macro themes related to Sustainable Furniture Design, from the choice of green materials and sustainable manufacturing processes to the application of ergonomic principles and aspects. We will review relevant certifications and standards as well as the life cycle of sustainable furniture, examining how sustainability is incorporated at each stage of the design and production process.

In addition, we will present examples of innovative designs that demonstrate how creativity can align perfectly with the ideals of sustainability, producing furniture that are both functional and ecological. Finally, we will discuss future trends in the field, considering technological advances and the evolving expectations of consumers.

This literature review aims to provide a solid foundation for Design by presenting an in-depth and critical view of the concepts, practices and challenges of Sustainable Furniture Design.

2 METHODOLOGICAL PROCEDURE

Initially, we conducted a comprehensive Google Academic platform search using English, Spanish and Portuguese terms: "sustainability design furniture". This search gave us a total of 740 results. Of these, we filter the articles. We focus our selection on scientific articles published in peer-reviewed journals, ensuring the quality and reliability of the sources. After an analysis of the titles and abstracts, we carefully selected 16 articles that were aligned with the scope of our systematic review. These articles addressed relevant topics related to Sustainable Furniture Design.

Each of the 16 selected articles has been linked into an Excel spreadsheet. Topics covered included: Title, Authors, Summary, Objectives, Results, Main Conclusions, Relevant Concepts and Theories and a Brief Important Discussion. This organization allowed a detailed

analysis of the contents of the articles. To identify the most relevant terms present in the selected articles, we use the WordClouds.com ® tool to generate a word cloud. This helped us visualize the most frequent and important keywords in the context of Sustainable Furniture Design.

All the articles' files were organized in the Mendeley ® software for a more detailed bibliographic analysis and easy access to the complete texts. This allowed for better organization and retrieval of sources. To understand the interrelations between the articles and identify themes or terms central to the revised productions, we perform bibliometric analyzes using the VOSviewer ® tool. This analysis provided us with valuable information about the knowledge network in the field of Sustainable Furniture Design (Silva Cavalcante, 2023; Silva Cavalcante & Araujo-Silva, 2023).

Finally, we conducted a narrative literature review, addressing the macro themes proposed in the design of the review, such as: Sustainability in Furniture Design, Sustainable Materials for Furniture, Sustainable Manufacturing Processes, Design and Ergonomics, Circular Economy in Furniture Design, Environmental Impact in Furniture Production, Innovative and Creative Sustainable Design, Sustainable Certifications and Standards, Sustainable Furniture Lifecycle and Future Trends in Sustainable Furniture Design.

This methodological process ensured the comprehensiveness and reliability of the literature review, providing a solid basis for the critical analysis and synthesis of information related to Sustainable Furniture Design.

3 RESULTS AND DISCUSSION

Table 1 presents a comprehensive and detailed overview of selected research in the field of sustainable furniture design. This table consists of valuable information about each article, including article title, authors, abstract, objectives, key results, findings related to the development and design of sustainable furniture. Each row in the table represents an individual study that contributes to the broader understanding of how sustainability is being addressed in furniture design. The titles of the articles vary in subject matter, reflecting a range of focuses, from efficiency in the furniture industry to innovation to sustainable development.

The abstracts provide a concise overview of each study, while the objectives outline the purpose and intent behind the research. The key findings and conclusions highlight the key findings and implications of these studies, providing an in-depth understanding of the advances and challenges in the field. In addition, the table includes a discussion of the relevant concepts and theories, allowing a richer understanding of the theoretical foundations that underpin each research.

Table 1. Binding of selected articles to guide the elaboration of macro themes and structuring of the review of narrative literature.

TITLE	AUTHORS	OBJECTIVE	CONCLUSIONS
An Appraisal of Housing Satisfaction in South Africa Low Income Housing Scheme	Clinton O. Aigbavboa and Dr. Wellington D. Thwala	Assess residential satisfaction in different Government housing subsidy locations in Gauteng Province, South Africa.	A more systematic and comprehensive coverage of the subject is recommended through post-occupation assessments and assessments of occupant needs in housing benefit schemes.
Efficiency in the Furniture Industry in Brazil: The Impact of Commercial Opening	Ricardo Bruno Nascimento dos Santos, Francivane Teles Pampolha	To verify the impacts of commercial opening on the efficiency of the furniture industries in the	Trade opening led to regional inequalities and reduced efficiency, but increased productivity.

in the States and Regions of Brazil	dos Santos, Alexandre Gervásio Sousa	Brazilian states and their physical productivity.	Approaches to improve efficiency in states are recommended.
First and Second Phase of Human-Centered Design Method in Design of Exterior Seating	Sarah Szökeová, Lukáš Fictum, Milan Šimek, Alena Sobotkova, Marek Hrabec, Danijela Domljan	Explore the first and second phase of human-centric design in the design process of exterior furniture.	The importance of user-centric design methods and market research in the design process.
The visual interface of 'comprehensive design'	Iva Kostešic and Fedja Vukic	Explore the visualization and interface of the concept of "comprehensive design" over time.	Highlights the importance of intersecting design, visual communication, design history, and data visualization.
Innovation for Sustainable Development as a Factor of Competitiveness for Organizations: A Duratex Case Study	Marta Fabiano Sambiase, Marcos Antonio Franklin, Jaqueline Alfim Teixeira	Identify whether sustainable business innovations influence Duratex's competitiveness.	Sustainability-oriented management and product and process innovations contribute to the company's competitiveness.
Flexible Furniture Design And It's Reflection On The Interior Spaces (Turkish University Dormitory As A Model)	Mohamed Hassan H. Alhilo, Change Reda Hussein	Identify innovative capabilities in flexible furniture design that contribute to practical solutions suitable for users.	The research highlights the importance of flexible furniture in limited environments and its contribution to the functionality and aesthetics of spaces.
Investigating the Influence of Co-Design on Design Process for Developing New Products	Mr. Mobeen Shaukat	Explore how co-design influences the design process and design strategy of companies.	Co-design is crucial to shaping the companies' design strategy and to engaging customers in the product development process.
Contributions to the implantation of furniture pole in the central region of Tocantins	Jorge D'Ambros, Joaquim Carlos Gonçalez, Humberto Angelo	To analyze the feasibility and impact of the formation of a furniture complex in the central region of Tocantins.	The formation of a furniture pole in the region can bring economic, social and environmental benefits, but it requires effective management strategies.
Quantification of the environmental quality of wooden furniture	Kátia Andréa Carvalhaes Pego	Develop a methodology to quantify the environmental quality of wooden furniture and verify its effectiveness.	The methodology proved to be effective, evidencing the economic and manufacturing viability of its application in the design of wooden furniture.
Sustainability in Planned Furniture Business in Manaus City: A Responsible Way	Anne Karoline Santos de Sousa, Cristiane Michiles Kuriyama, Joaquim Cassiano Urquia Erace, Mary Lúcia Tavares Andrade, Vanessa de Oliveira Alves,	Explore sustainable practices in furniture companies planned in Manaus and assess their impact on the market and on environmental preservation.	The adoption of sustainable practices is essential for the balance between economic development and environmental preservation in Manaus.

	Weuler Souza Arce		
Combining social design with Sustainable PSS: a Brazilian case study	Bruno Vinicius da Palma Novaes; Caroline Marengone Altizani; Tomás Queiroz Ferreira Barata	Investigate how social design combined with the S.PSS can be applied to create sustainable and social solutions.	The importance of social design combined with S.PSS to create solutions that improve people's lives and promote sustainability.
Study of the Properties of Reclaimed Wood in Furniture Manufacturing	Kristiin Bauer	Understand and determine properties of recovered wood for use in the manufacture of furniture.	The recovered wood, in spite of its reduced physical and mechanical properties, has potential for use in the manufature of furniture.
Scenario Analysis of Profits in Further Processing Lumber to Furniture in Ghana for Export: A Case Study of a Local Firm	Peter Kessels Dadzie, Kwasi Frimpong-Mensah, Martin Amoah, Ernest Boampong	Assess whether additional processing of wood for furniture is economically feasible and identify the most profitable scenarios.	Further processing of wood for garden furniture is cost-effective and should be encouraged. Scenario analysis helps you make economic decisions.
Selected Challenges of Closed-Loop Economy in the Furniture Industry	Marwa Dahche, Grzegorz Kowaluk	Analyze challenges and potential of the closed economy in the furniture industry, focusing on upcycling and reuse of materials.	Highlights the importance of the closed economy and upcycling in the furniture industry, with potential for innovation and sustainability.

Source: Cavalcanti, 2023

Figure 1 presented is a keyword co-occurrence map generated from a bibliometric analysis of the articles listed in the provided table, using the VOSviewer software. This map visualizes the connections between different key terms extracted from the articles, illustrating the most frequent and relevant thematic areas in the literature on sustainable furniture.

On the map, it can be seen that terms such as "circular economy", "recycling", "innovation" and "digitalization" are prominent, which suggests that these are key concepts within the field of sustainable furniture design. The closeness between these words indicates the relationship between them. For example, the link between ‘circular economy’ and ‘recycling’ suggests that recycling is a key component of the circular economy within the furniture sector. This is aligned with the current perspective that the circular economy in furniture design is becoming more prevalent, with an emphasis on reuse and recycling.

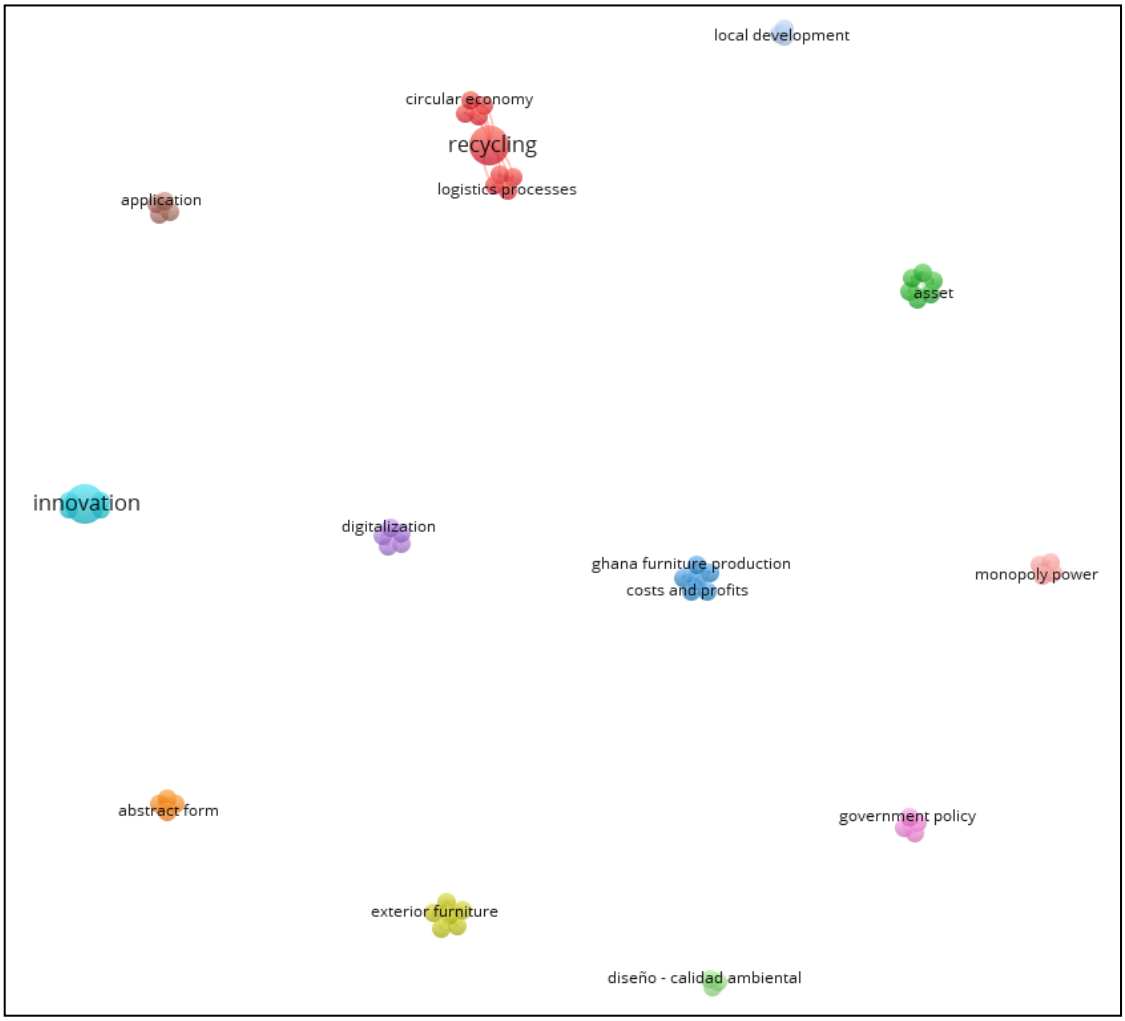


Figure 1 - Correlation network between the themes of the articles selected for the literature review (n=16).
Source: Cavalcanti, 2023

The word "innovation" positioned close to "digitalization" may indicate that digital technology is playing a significant role in innovation in the furniture industry. Terms such as "furniture production in Ghana" and "monopoly of power" may highlight specific case studies or market issues addressed in the articles, while "external furniture design" and "environmental calidad" (environmental quality) may represent specific research niches within the field.

The discussion around this map may focus on the interconnectedness of these terms and how they reflect current trends and challenges in the design of sustainable furniture. The analysis can address how sustainable practices are being integrated along the value chain of the furniture industry, from product design and design to production, distribution and post-consumption. In addition, the discussion can explore how innovation and digitalization are facilitating new forms of production and consumption that support the transition to the circular economy and help reduce the environmental impact on furniture production.

The word cloud (Figure 2) presented is a graphical representation that highlights the most frequent terms in the articles related to the design of sustainable furniture. The most prominent words, such as "wood", "design", "furniture", "innovation" and "need", reflect the central themes and concerns prevalent in the field. This visualization facilitates the identification of trends and focuses of interest in existing literature and can serve as a guide for future discussions and research development.

Looking at the words ‘wood’ and ‘furniture’, it is immediately clear that the material is a central element in the production of furniture and that the sustainability of this resource is a crucial consideration. The term "design" together with these concepts reinforces the importance of innovation and conscious planning in the development of products that are not only aesthetically pleasing, but also environmentally responsible.

The word "innovation" suggests an ongoing search for new solutions and methods that can improve sustainability in the sector. This innovation may be related to the use of materials, the efficiency of manufacturing processes or the implementation of circular economy practices, as indicated by the term "downcycling", which suggests the transformation of lower value products into new materials or products.

"Competitiveness" appears as a key theme, highlighting the need for the furniture sector to remain economically viable while adopting sustainable practices. This implies a balance between operational efficiency, meeting consumer demands, and environmental responsibility.

The discussion on this cloud of words can address how the different terms relate to each other and to sustainability issues. For example, how can companies innovate in their design and production processes to improve sustainability without compromising quality or competitiveness? How can the "preservation" of wood, a vital natural resource, be ensured through conscious design and manufacturing practices? In addition, the role of "social aspects" suggests a concern with the human implications of furniture design, such as ergonomics, inclusiveness and the social impact of production.

This word cloud can be a starting point for deepening our understanding of the challenges and opportunities in the field of sustainable mobile design, encouraging additional research that addresses these interconnected themes and promotes a more sustainable future for the furniture industry.



Figure 2 - Word cloud with the data that was recorded from the selected articles for the literature review (n=16).
Source: Cavalcanti, 2023

4 SUSTAINABILITY IN FURNITURE DESIGN

Sustainability in furniture design is a topic of growing importance in the field of industrial design, both in academia and in practice. With environmental awareness on the rise and the urgency of the climate crisis, designing sustainable furniture has become a necessity, not a choice anymore. This need is reflected in the articles analyzed (Table 1), which highlight the efficiency in the furniture industry and the importance of human-centered design.

First, it is crucial to understand sustainability in furniture design as an integrated approach. It is not limited to the use of environmentally friendly materials or low-carbon production techniques, it encompasses user satisfaction and production efficiency. Efficiency in the furniture industry, as discussed in the articles, is a matter of maximizing production and minimizing costs, and optimizing resource use and reducing waste. This efficiency aspect is directly related to sustainability, as efficient processes tend to be more sustainable (Beckmann, Sivarajah, 2021; Despeisse et al., 2022).

In addition, human-centric design is an essential component of sustainable furniture design. This approach emphasizes the creation of products that meet the functional needs of users, and consider their well-being and comfort. Human-centered design therefore goes beyond aesthetics and functionality, addressing issues such as ergonomics, accessibility and inclusion. When applied to the design of sustainable furniture, it ensures that the products are environmentally sustainable, and sustainable in terms of long-term satisfaction and usability for users (Giacomin, 2014).

The intersection between production efficiency, user satisfaction and environmental impact is where true sustainable furniture design shines. For example, furniture that is designed to be collapsible and easy to repair contributes to product longevity and reduced waste. At the same time, these designs can offer flexibility and adaptability, increasing user satisfaction (Cruickshank & Trivedi, 2017).

In recent academic articles, there is a growing tendency to explore new materials and technologies in the context of sustainability. Innovative materials, such as certified wood, recycled plastics and bioplastics, are increasingly being used. These materials reduce environmental impact and open up new aesthetic and functional possibilities for designers (Grbac et al., 2007; Ashby, 2013; Yuksel, 2016; Munteanu, 2021).

Therefore, sustainability in furniture design is a multifaceted area that requires a holistic approach. The integration of environmental considerations, production efficiency and human-centric design is essential to creating products that are truly sustainable. As the industry progresses, it is critical that designers continue to innovate and seek solutions that balance all these considerations in a harmonious manner.

5 SUSTAINABLE MATERIALS FOR FURNITURE

The choice of sustainable materials in furniture design is a critical aspect that influences both the production phase and the product's post-use life cycle. Materials such as certified wood, which promote sustainable forest management, and recycled materials, which support the circular economy, are essential to minimize environmental impact during production and provide sustainable alternatives for disposal and recycling (Xiong et al., 2020).

Innovating in sustainable materials is crucial to meet the growing demand for environmentally friendly products. The exploitation of biodegradable materials, including natural fiber compounds, offers environmentally responsible alternatives compared to traditional materials. Similarly, recycled plastics contribute to waste reduction and responsible use of resources (Peters, 2014; Munteanu, 2021).

One of the challenges in using sustainable materials is to understand and compare life cycle assessments (LCAs or LCAs) of different manufacturing processes. Transparency and understanding of environmental impacts during manufacturing are key in selecting materials for indoor environments. In addition, it is important to consider issues related to consumption, specifications for the use of materials and products, impacts on indoor air quality and end-of-life options of products (Bianco et al., 2021).

The selection of sustainable materials in furniture design involves not only the choice of "green" materials, but also the way these materials are used in the design process. Interior designers and architects must understand the lifecycle impacts of designs to address the greatest environmental impacts of their practice, specifying materials and products. Thus, it creates a design that is not only sustainable, but also aesthetically pleasing and functional for users (Nair et al., 2013).

6 SUSTAINABLE MANUFACTURING PROCESSES

Sustainable manufacturing processes in furniture design have evolved significantly, with emphasis on production efficiency and the need for adaptive strategies to maintain sustainability. Currently, these processes include the use of renewable energy, waste reduction and supply chain optimization to reduce greenhouse gas emissions (Grujovic et al., 2017; Ma et al., 2021).

One of the crucial aspects is the adoption of the "Triple Bottom Line" concept, which integrates economic, environmental and social aspects into a unified business model. This improves the quality and sustainability of products, impacts of production and post-consumption, also ensuring the company's growth. In addition, product customization for flexible and sustainable production is highlighted, where mass customization production environments need to produce small batches of products flexibly and quickly. Ideally, customers should be able to customize their products, considering the impact of this customization on sustainability (Hollos, Blome & Foerstl, 2012).

In this context, an Intelligent Product Configuration System (SCPI or SPCS) can be used. This system helps bridge the gap between customer needs and manufacturing capabilities by providing sustainability information such as feedback. Integrating product design and engineering into early product configuration steps through an SPCS plays a crucial role as it provides a graphical interface for users to customize desired products and receive system sustainability information (Wong & Hernandez, 2012; Chiu & Chu, 2012).

These advances demonstrate how manufacturing processes in furniture design are becoming increasingly sustainable, with a holistic approach that considers multiple dimensions of sustainability, from product design to production and end use.

7 CIRCULAR ECONOMY ENVIRONMENTAL IMPACT ON FURNITURE PRODUCTION

The circular economy in furniture design and the environmental impact in furniture production are intertwined and crucial topics today. The archive's perspective on these themes emphasizes the need for sustainable innovation and sustainability-oriented management. Currently, the circular economy in furniture design is becoming more prevalent, with a focus on reuse, recycling and design for disassembly. This approach aims to minimize waste and maximize the efficient use of resources, turning waste into new resources.

In the context of the environmental impact on furniture production, there is growing concern about the carbon footprint and the full life cycle of products. This approach includes

the consideration of CO2 emissions and the use of natural resources, aiming at reducing environmental impact at all stages of the product life cycle (Oliveira, França & Rangel, 2018; Silva Cavalcante, 2023).

The transition to the circular economy in the furniture sector involves significant challenges, but also offers opportunities for innovation and sustainable development. Companies in the sector are increasingly focused on developing skills and skills needed to support this transformation (Silva Cavalcante & Araujo-Silva, 2023).

8 CONCLUSION

Concluding an article that covers themes as broad and interconnected as sustainability in furniture design requires a vision both reflective and forward-looking. Throughout this article, we explore the complexity inherent in incorporating sustainable practices into the design and production of furniture. We highlight the imperative need for innovation, the adoption of sustainable materials and the importance of embracing the principles of the circular economy to mitigate environmental impact.

It became evident that sustainability is not an isolated facet, but a complex tessitura of material choices, design decisions, production methods and post-consumption considerations. Through the analysis of academic literature and discussion of relevant keywords in the field, we identify that while there are significant challenges, there are also substantial opportunities for transformation and innovation.

The journey towards more sustainable practices in furniture design is continuous and dynamic, requiring a holistic approach that balances economic demands with environmental and social responsibility. We concluded that the furniture industry is in a unique position to lead by example, demonstrating how innovation and sustainability can go hand in hand for a greener and fairer future. As we move forward, it will be critical that all designers and manufacturers, consumers and policymakers work together to promote a truly circular and sustainable product lifecycle.

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