

Original Article

Environmental, social and governance (ESG) and innovation in the construction sector: Systematic Literature Review

Ambiental, social e governança (ESG) e inovação no setor da construção:
Revisão Sistemática da Literatura

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ABSTRACT

Purpose – To analyze the evolution of Environmental, Social and Governance (ESG) and innovation in the civil construction industry, focusing on innovative and sustainable practices, as well as ways of measuring the level of construction companies in these themes.

Design/methodology/approach – A Systematic Literature Review approach was used. The Web of Science and Elsevier Scopus Databases, from 2017 to 2022, were used for data collection, based on a set of keywords and Boolean operators (“sustainable development” & “framework” & “measurement” & “environment”). Using the Zotero Software, 488 papers were classified and organized according to the publication date, main content, proposals for sustainable and innovative tools and techniques. The papers were analyzed in the VOSviewer Software.

Findings – There is an Asian predominance in the volume of publications and networks of strong connections in clusters by countries. The authors tend to look for papers from the same region as a reference, going against the concept of globalization of ESG and innovation themes and the condition of replicability of practices. Among the exemplified practices, there are replicable models and initiatives, as well as incipient innovative construction materials and methods in search of consolidation.

Originality/value – Amid the current and growing discussion about innovation and ESG in organizations, it is noted that the civil construction sector still lacks better performances in these themes. This paper aims to contribute to the advancement of the discussion in the sector, bringing together works found in recent literature.

Keywords: Performance measurement; Civil construction; Socio-Environmental Governance (ESG); Innovative and sustainable practices

RESUMO

Objetivo – Analisar a evolução dos temas de ambiental, social e governança (ESG) e inovação na indústria da construção civil, com foco em práticas inovadoras e sustentáveis, bem como formas de mensuração do nível das construtoras nos temas.

Desenho/metodologia/abordagem – Utilizou-se uma abordagem de Revisão Sistemática da Literatura. As bases de dados Web of Science e Elsevier Scopus, de 2017 a 2022, foram utilizadas para coleta de dados, com base no conjunto de palavras-chave e operadores booleanos (“desenvolvimento sustentável” & “framework” & “medição” & “ambiente”). Foram classificados 488 artigos, descritos quanto à data de publicação, conteúdo principal, propostas de ferramentas e técnicas sustentáveis e inovadoras. O Software Zotero foi utilizado para classificar e organizar as publicações, que posteriormente foram analisadas no Software VOSviewer.

Resultados – Há predominância Asiática no volume de publicações e redes de conexões em clusters por países. Autores tendem a buscar artigos da mesma região como referência, não seguindo o conceito de globalização dos temas ESG e inovação e a condição de replicabilidade das práticas em outros países quanto às temáticas. Em meio às práticas exemplificadas, encontram-se modelos e iniciativas replicáveis, além de materiais e métodos construtivos inovadores incipientes em busca de consolidação.

Originalidade/valor – Em meio à discussão atual e crescente sobre inovação e ESG nas organizações, nota-se que o setor da construção civil ainda carece de melhores desempenhos nesses temas. Este artigo visa contribuir para o avanço da discussão no setor, reunindo trabalhos encontrados na literatura recente.

Palavras-chave: Medição de desempenho; Construção civil; Ambiental; social e governança (ESG); Práticas inovadoras e sustentáveis

1 INTRODUCTION

Civil construction companies are among the main drivers of global development, contributing to the transformation and growth of cities, to the lives of citizens who live from this sector and to the development of the economy through the generation of jobs and income and the consumption of materials, energy, water and raw materials (Gomes, 2018). In Brazil, the construction sector is quite comprehensive. According to data from the 2019 Annual Survey of the Construction Industry – (PAIC) (IBGE, 2019), 125,067 companies in the civil construction sector employed just over 1.9 million people and had costs and expenses of approximately USD 67 billion, of which USD 46 billion in incorporations, works, construction services and building materials, and USD 21 billion in personnel expenses, such as salaries, withdrawals and others.

However, due to the highly voluminous construction process, the civil construction sector has the potential to have a great impact on the environment. According to the World Bank's What a Waste 2.0 report (Kaza et al., 2018), in 2017, approximately 2 billion tons of construction and demolition waste were generated worldwide. In addition to this, the same report presents a projection that by 2050 this number will reach 3.4 billion tons, which would represent an increase of 70%. Of this high estimated volume, 31% comes from building construction, 46% from road and bridge construction, and 23% from other types of construction (EPA, 2020). In Brazil, the scenario is not so different. Brazilian cities generate 79 million tons per year of Construction and Demolition Waste, mainly composed of mortar (63%) and concrete and blocks (29%), given the predominance of construction standards in Brazil that use concrete (ABRECON, 2015), with 92% of the total CDW being collected by certified companies. However, only 60% of the material collected were disposed of in sanitary landfills (ABRELPE, 2019).

In addition to the volume of CDW generated, the construction sector is one of the human activities that generate most liquid and gaseous waste, and is also one of the main consumers of raw materials, water and energy. According to Resende et al. (2021), the high generation of both kinds of waste comes from renovation, demolition and lack of efficient management in the sector. Regarding construction inputs, The American organization US Green Building Council reports that civil construction currently consumes 21% of all treated water on the planet, with 14% being the responsibility of buildings (UNESCO, 2021). In Brazil, and according to the water thematic committee of the Brazilian Council for Sustainable Construction (CBCS), 50% of the drinking water supplied to urban areas is destined for civil construction, on average. Regarding energy consumption, it is estimated that buildings are responsible for approximately 40% of global energy expenditure (Li et al., 2021). As a result of the aforementioned factors, several authors agree that this sector is inherently connected to the topic of sustainable development (e.g. Capaz & Nogueira, 2015; Gomes, 2018; Işik & Aladağ,

2016; Pacheco Jr., 2020; Resende et al., 2021; Ripardo, 2022; Sousa-Zomer & Miguel, 2018; Vieira, 2021; Zhou et al., 2020).

Thus, one of the main challenges of the civil construction industry is to keep a constant growth, emphasizing its importance for the development of societies, but consuming less material resources and generating less waste in its processes. To achieve this challenge, as shown by Kneipp et al. (2017), two terms have gained attention over the past decade: ESG and innovation. In this sense, the innovation necessary for the growth of corporations must come from a perspective of sustainable and social development.

The main objective of this paper is to analyze the evolution of the socio-environmental governance (ESG) and innovation in the civil construction industry, focusing on sustainable practices, from an environmental, social and governance point of view, and ways of measuring the performance – mostly economic/financial – of construction companies in these areas. Starting from this point, it is expected to contribute to the advancement of the discussion on the subject, bringing together recent works and analytical results on main publications, authors and journals.

2 ENVIRONMENTAL, SOCIAL AND GOVERNANCE AND INNOVATION IN CIVIL CONSTRUCTION COMPANIES

According to Costa and Ferezin (2021, p.2), “in the 21st century, the simplistic idea that only the produced capital can sustain an organization is no longer adequate. At this moment, organizational communication finds its due place, showing aspects that support important decisions for the growth of institutions”. In this scenario, organizations have widely discussed the ESG concept, due to the exercise of citizen awareness or what the literature defines as consciousness. The ESG encompasses the criteria related to the Environment, Social and Governance of organizations (Purvis et al., 2019; Alexandrino, 2020). ESG, used at a United Nations meeting in 2004, to discuss environmental issues and guidelines for solving problems, has

become one of the main ones to address the 2nd issue and has become intrinsic to the concept of sustainable development in organizations and in society as a whole (Gillan et al., 2021). Then, a decade later, in 2015, in agreement with the 193 nations present at the assembly, the UN launched the Sustainable Development Goals, proposing the SDG 2030 agenda, with goals and indicators for each area of development, so that all SDG could move towards a globalized sustainable panorama (ONU, 2018d).

The construction sector is part of SDG 9 on industry, innovation and infrastructure (UN, 2018a), but has secondary targets in SDG 6, drinking water and sanitation, SDG 11, sustainable cities and communities, and SDG 12, responsible consumption and production (UN, 2018b, 2018c, 2018d). By achieving the SDGs related to the civil construction sector, the construction companies will be able to respond not only to the UN's global SDGs but also to their stakeholders, i.e., governments, shareholders, customers, and society. In addition to the main point, that is contributing to the preservation of the planet.

However, how to make investments in sustainability and innovation compatible with financial performance that generates competitive advantage is not yet a subject fully understood by corporations, especially for smaller companies with less resourceful financial resources, according to Preston e O'Bannon (Alexandrino, 2020). To fill this gap, either for society, for the preservation of the environment or for the future of organizations, several studies were carried out in the last decade, describing the relationship between innovative and sustainable practices with the performance and performance of the civil construction industry (e.g. Ajayi et al., 2017; Alexandrino, 2020; Arruda Castro, 2016; Banihashemi et al., 2017; Chen et al., 2016; de Franco, 2020; Eilers et al., 2016; Julison et al., 2017; Kavishe et al., 2019; Mangialardo et al., 2019; Oke et al., 2019; Powmya et al., 2017; Xue et al., 2018).

Even so, it is observed that companies in the civil construction area, for the most part, are in a slow process of evolution in terms of sustainability, compared to the

speed with which the environment is degraded. Almeida Gil (2021) considers that the actions of development and construction companies in Brazil are timid in the face of the movement that companies from other sectors such as financial, banking, hospital, and manufacturing industry play in the ESG context. According to this author, there is space to be explored within the sustainable universe of constructions, but for that, the construction industry needs to fight its own historical conservatism and reticence in relation to structural changes that need to be implemented.

3 RELEVANT PUBLICATIONS ON ENVIRONMENTAL, SOCIAL AND GOVERNANCE AND INNOVATION IN CIVIL CONSTRUCTION

In the study by Gonzalez-Caceres et al. (2019), an extensive review of eighteen tools used for property renovation and retrofit for civil construction was carried out, grouped into three categories: renovation assessment, financial assessment and knowledge transfer. From this review, it can be concluded that development and innovation in retrofitting tools benefit a wide range of stakeholders, including researchers, organizations and even countries.

These authors concluded that the analyzed tools deliver improvements that vary depending on the variables of each company. Only a few tools included cost and payback time as variable to define the best energy efficiency strategy, while others had more specific physical construction conditions, such as tightness or moisture problem solving. Regarding the tools for financial assessment, it was observed that all of them work as an online platform and that they assist organizations to collect information for the database that allow simulations in specialized software. On the other hand, knowledge transfer tools proved to be more complex, demanding more detailed inputs, becoming more attractive to owners with greater knowledge of the subject, but allowing achieving results that are more accurate.

Regarding the assessment of sustainable constructions, Yadegaridehkordi et al. (2020) set out to research which were the most used criteria and, despite finding

in the literature few studies on the use of green building assessment systems, they selected, through a diffuse multicriterial decision approach, 6 criteria, 17 sub-criteria and 54 sustainability indicators associated in the manufacture of green buildings in Malaysia. The results showed that, in the index built by the authors, energy efficiency and internal environmental quality were the most important criteria, with the respective sub-criteria design and performance and lighting, visual and acoustic comfort.

Regarding the economic performance of construction companies considered sustainable, Onubi et al. (2020) carried out a study to verify whether the adoption of green practices in construction projects in Nigeria influenced economic performance through environmental performance. The study was based on sample research through questionnaires answered by contractors responsible for 168 construction projects. The questionnaires contained four parts, the first for collecting information from the projects, the second questions about green practices at construction sites, the third questions about environmental performance and the last about economic performance. The results showed that the adoption of green practices directly at the construction site helps contractors to have less costs with waste management, litigation, energy consumption, among others, which will offset the cost of adopting the practices.

During a study on the incorporation of ESG factors in decision-making investments, Schumacher (2020) compares different approaches in the literature for analyzing the relationship between environmental and social responsibility and the financial performance of companies and concludes that the main difference between research in the ESG area is the way of measuring sustainability. While older authors focused on single sustainability criteria, such as measures of pollution or waste generation (see Cohen et al., 1997; Konar & Cohen, 2001) 21st century literature such as Galema et al. (2008) and Manescu (2011) consider a general sustainability screening, considering corporate social responsibility classifications.

Alexandrino (2020) presents another study relating indicators associated with the topic with the economic-financial performance of organizations and infers that ESG performance exerts a positive influence, both measured by indicators present in accounting books, such as Return on Assets and Net Income, and by indicators measured by the market, which evaluate companies from the point of view from the point of view of foreign investors.

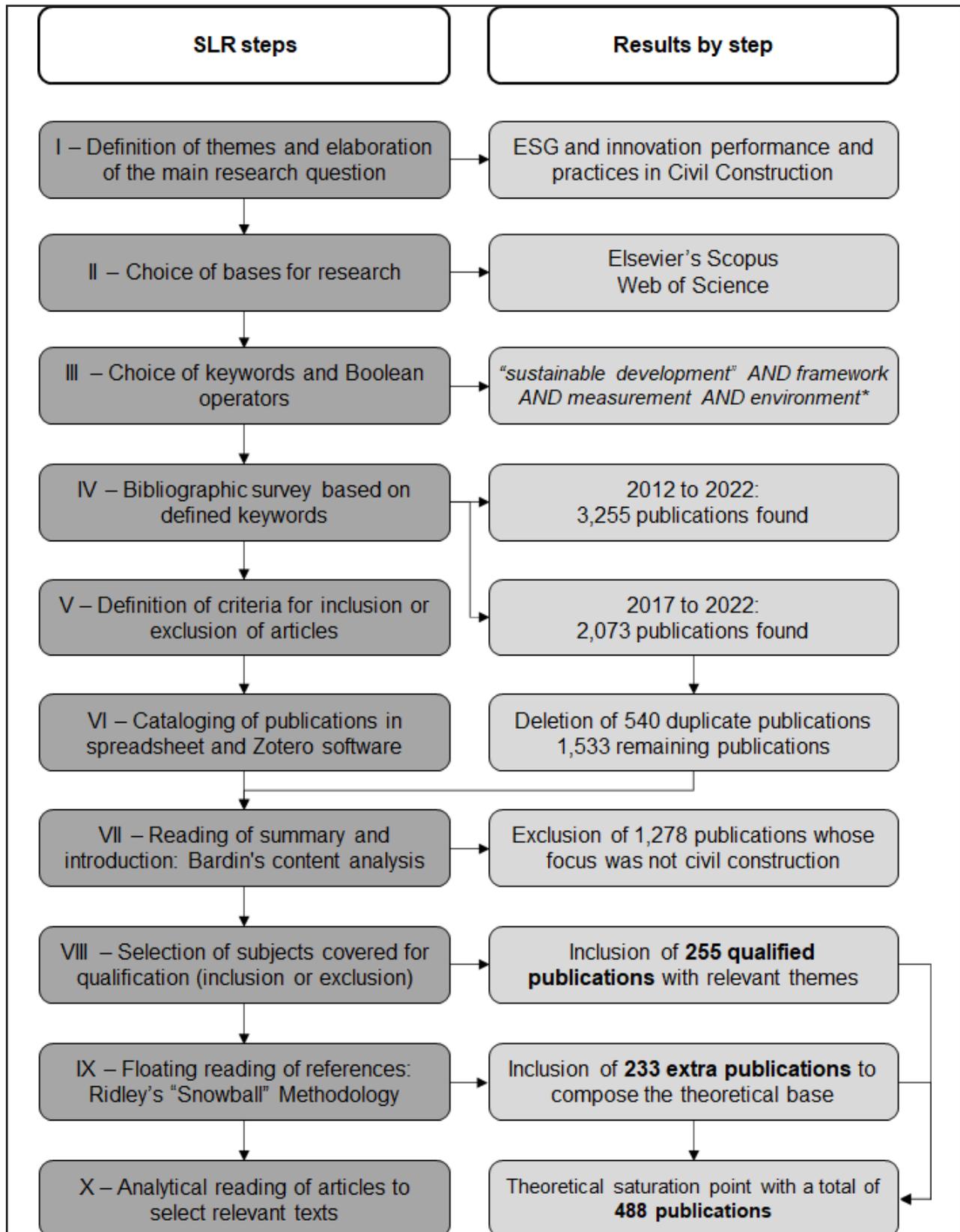
The common point of the organizational performance of builders, developers and contractors, regardless of the degree of development of the country in which they are located, is that it needs to be translated into financial performance (Garcia, 2017), one of the pillars of the Tripod of Sustainability. It is noted, in the publications found, that the objectives of the authors, although different – improvement in the level of service, optimization of deliveries, cost reduction, increase in efficiency, use of collaborative management, valuation of the real estate market – converge to the metric financial.

Given the above, this study aims to analyze the evolution of socio-environmental governance (ESG) and innovation in the construction industry, focusing on sustainable practices and ways of measuring the performance of construction companies in these areas.

4 METHODS

This work aimed to analyze the evolution of socio-environmental governance (ESG) and innovation in the civil construction industry, focusing on sustainable practices and ways of measuring the performance of construction companies in these areas. The Systematic Literature Review was supported by the methodology described in Figure 1, based on the steps proposed by Tranfield et al. (2003) and Denyer & Tranfield (2009).

Figure 1 – Steps and results of the Systematic Literature Review (SLR)



Source: elaborated by the author, based on SLR steps proposed by Tranfield et al. (2003) and Denyer & Tranfield (2009)

The themes – Environmental, Social and Governance (ESG), Sustainability and Innovation in civil construction – and databases – Web of Science (WoS) and Elsevier's SCOPUS – chosen for the bibliographical research were defined. The keywords and Boolean operators used to carry out the research were “sustainable development” and framework and measurement and environment*.

In order to assess the volume of publications in the last decade, a first baseline survey was carried out considering publications between 2012 and 2022 by authors from all over the world, with 3,255 publications being found. However, with the aim of evaluating contemporary research with the greatest impact on the civil construction sector, the same research was carried out considering only the last 5 years (the specific period from January 2017 to March 2022), which represented 64% of the research publications basis performed initially, that is, a total of 2,073 publications.

Publications from any country, in the construction sector, were accepted, which presented the use of innovative and sustainable construction methods or materials, as well as performance indicators related to innovation and sustainability factors. After excluding publications that were duplicated in the databases, the total number of remaining publications was 1,533.

The publications contained in the bibliography were studied and referenced as they were considered relevant to the research objective. Subsequently, they were sorted and filed into folders in Zotero by publication type.

All titles were analyzed using the content analysis method proposed by Bardin (2011), seeking content related to specific sustainability themes in construction, complemented with evidence, examples and discussing the general concept of ESG and innovation topics. In cases of doubt or to confirm the selection made, the abstracts and introduction or, in some cases, the entire papers were read. In this way, 1,278 publications not focusing on civil construction were excluded, such as those on architecture, archaeology, biology, medicine, administration, hydrology, chemistry

and other branches of industry, as well as publications focusing innovative practices in other engineering areas, such as infrastructure, electrical, naval, mechanical, automation and mining.

After finishing the classification of publications, considering inclusion and exclusion criteria, 255 publications were selected and, from these, searches were carried out in the bibliographic references, according to the “snowball” methodology proposed by Ridley (2008), where the publications considered relevant to the objective of the Systematic Literature Review (SLR) were retrieved until reaching a theoretical saturation point, when new references did not add more important and complementary information, as recommended by Adams et al. (2006).

In this way, another 233 theoretical and empirical papers were included in the bibliography, which were classified and filed in specific folders for each factor, as was done with the previous base research. Thus, a qualified base of 488 publications was totaled.

Examples of ESG practices and innovation implemented in at least 80 countries were found in the selected literature, from the point of view of different stakeholders: government institutions, academia and students, builders and contractors, communities affected and/or benefited, users of housing units and others.

To perform the qualification of the 488 publications included, during the content analysis, an electronic spreadsheet was built to identify the main subject of each publication. Thus, a separation of relevant subjects was carried out, about ESG and innovation specifically in civil construction and preferably in the residential segment. Likewise, the separation was carried out in the Zotero software, in order to assist in the accuracy and agility of searches of reference texts for each subject.

The classification by main subjects of the publications, as shown in Table 1, resulted in 11 different groups.

The VOSviewer software was used to build and visualize bibliometric networks on the SLR. VOSviewer is a widely used software tool for bibliometric analysis and

has dozens of analysis possibilities, as explained by van Eck & Waltman (2010). With these analyses, the software assists in the understanding of important points of the systematic review, such as: bibliographic coupling and arrangements of citations and co-citations by author, by country, by journals, among others.

Table 1 – Publications on Environmental, Social and Governance practices and innovation in civil construction, by subject (2017-2022)

Addressed topic	n (%)
Sustainable construction methods	113 (23%)
Innovative and sustainable materials	89 (18%)
Environmentally and socially sustainable housing	71 (15%)
Financial performance of sustainable buildings	55 (11%)
Innovation in practice at works	38 (8%)
Sustainability assessment and measurement tools	28 (6%)
Building Information Modeling (BIM)	27 (6%)
Energy efficiency	20 (4%)
Social and environmental regulations in civil construction	18 (4%)
Recycling and waste reduction in works	16 (3%)
Sustainable renovation of community buildings	13 (3%)
Total publications	488

Source: elaborated by the authors

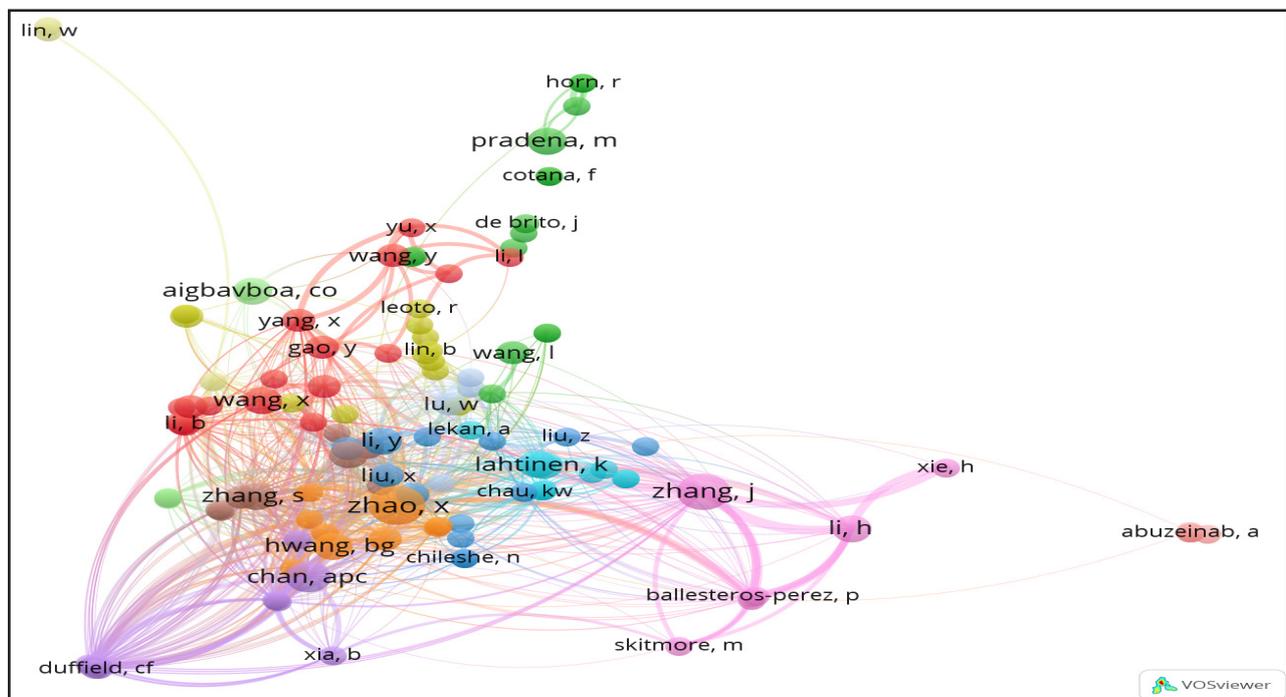
The technique of bibliometrics consists of measuring, statistically, the rates of production and dissemination of knowledge about a certain subject or area (Guedes & Borschiver, 2005). A good bibliometric analysis can help identify patterns of collaboration between authors and measure the current coverage of publications on a given subject, obtaining a global and specialized view of the literature (Bartz et al., 2019). These techniques have also been used to identify the most productive authors and journals in each area, in addition to finding paradigms in science that can be challenged, or gaps to be filled. (Pereira et al., 2019)

5 RESULTS AND DISCUSSION

5.1 Bibliometric analysis

The first analysis carried out in terms of bibliometrics of publications was the bibliographic coupling, consisting of measuring the relationship between two publications based on the number of common references cited by both, as illustrated in Figure 2.

Figure 2 – Bibliographic coupling of publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction (2017-2022)



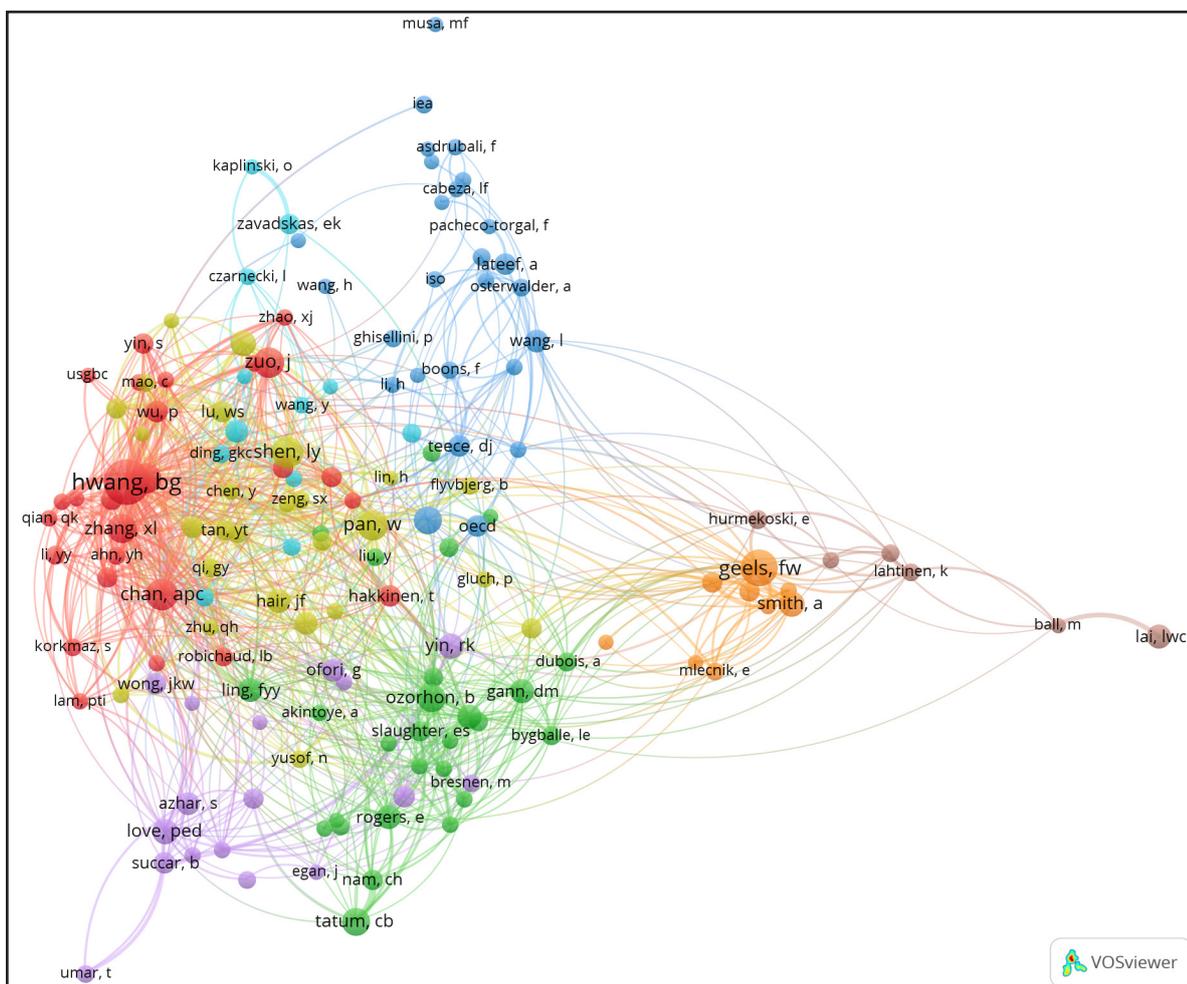
Source: elaborated by the author with the VOSviewer Software from the WOS and SCOPUS databases

Figure 2 demonstrates relevant facts in aspects of bibliographic coupling. In addition to the predominance of Asian authors (indicated by the colors purple, pink, blue, orange and red), the networks of connections, represented by these clusters, are very strong (deducible by the entanglement of connections between authors in the graph) and grouped by countries and regions. The size of the bubbles in the graph indicates the concentration of citations to a few authors from each country or region.

Thus, it is clear that the authors, when carrying out studies, use publications from the same region as references. This practice goes against the concept of globalization of the proposed themes of ESG and innovation and the condition of replicability of the practices.

The second analysis, as shown in Figure 3, shows the most cited authors publishing in the scope of ESG and innovation in civil construction.

Figure 3 – Most cited authors in publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction (2017-2022)

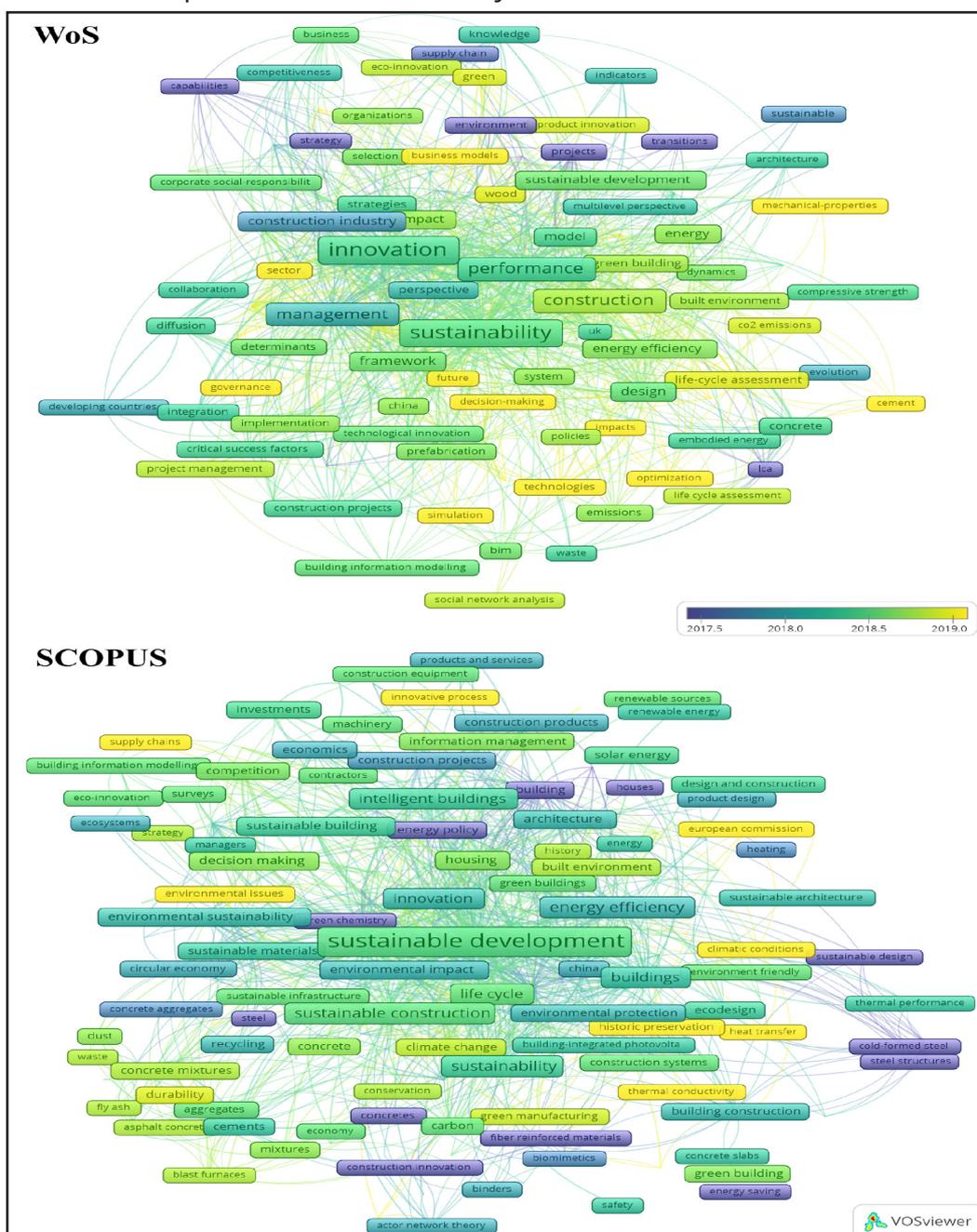


Source: elaborated by the author with the VOSviewer Software from the WOS and SCOPUS databases

In Figure 3, it is also observed that the most cited authors' publications on Environmental, Social and Governance practices, Sustainability and innovation in civil

construction are strongly grouped by countries and regions. The red, green and dark blue clusters that represent, respectively, China and neighboring countries, the United States and, finally, Eastern Europe and North Asia, indicate the countries that have the most authors publishing. There is a significant concentration in the network of connections, mainly within the red and green clusters.

Figure 4 – Most used keywords, per year, in publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction (2017-2020)



Source: elaborated by the author with the VOSviewer Software from the WOS and SCOPUS databases

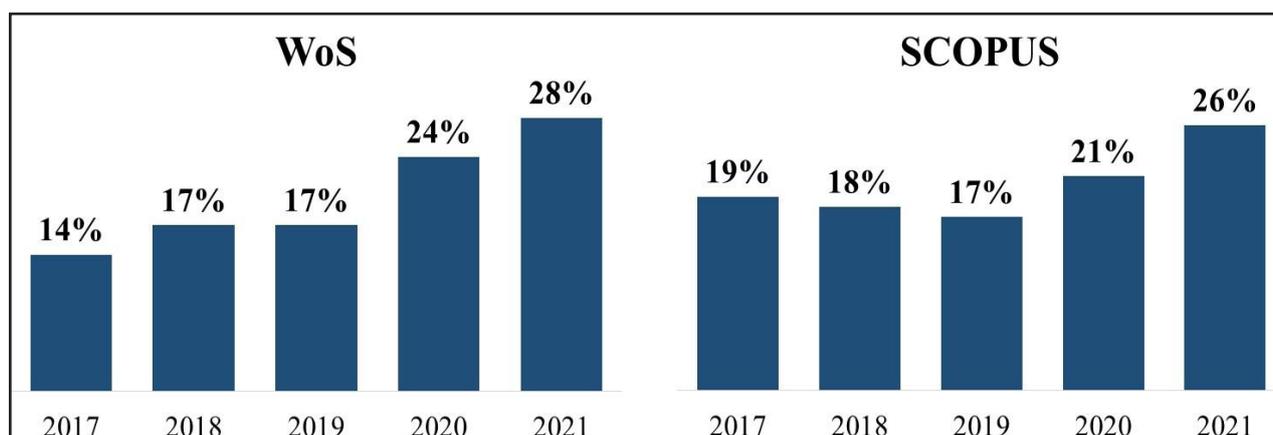
Afterwards, an analysis was carried out of the most used keywords per period in the WoS and SCOPUS databases about ESG and innovation in civil construction. The results are shown in Figure 4.

Observing Figure 4, we can see a mirrored position of the Web of Science (WoS) and Elsevier's SCOPUS bases. At WoS, terms (in yellow) focused on technology, optimization and decision-making processes, as well as consolidated themes cited longer ago (in purple and blue), such as the environment, life cycle assessment, projects and strategies. In the SCOPUS database, it is possible to identify which technical engineering and/or technology terms are widely seen in the 2017 publications, while in the most recent publications there is a greater use of terms such as climate condition and environmental problem

This mirroring of the most cited words, at first sight, could be considered as a divergence. However, when analyzing the entire evolution of the discussion on innovation and sustainability over the last decades, it is concluded that the journals that publish in each of these databases are updating and evolving on the themes, making the discussion broad and comprehensive.

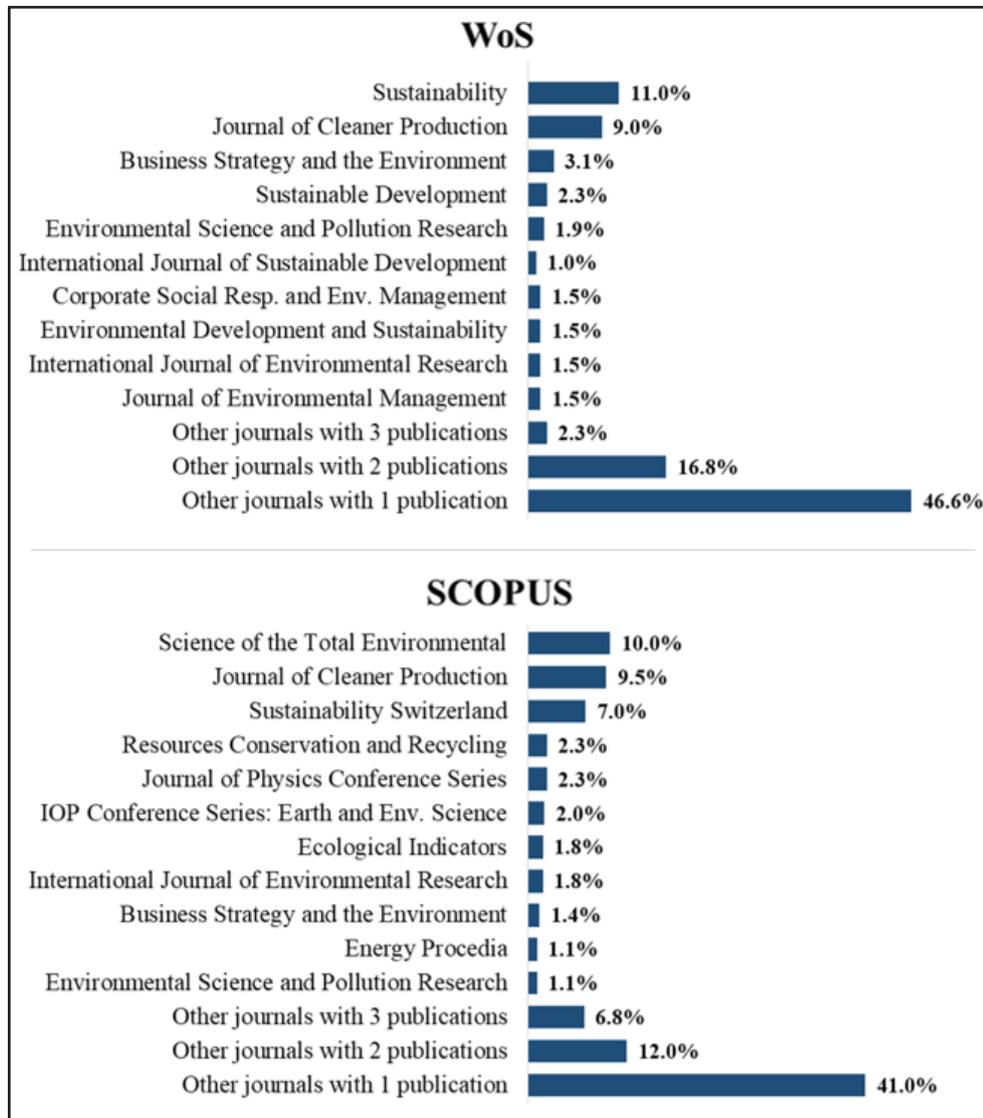
Figures 5 and 6 show the evolution of publications in the last 5 years in WoS and SCOPUS databases, in addition to indicating which journals published the most during the period in relation to Environmental, Social and Governance practices, Sustainability and innovation in civil construction.

Figure 5 - Distribution, per year, of publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction (2017-2022)



Source: elaborated by the author, based on the WOS and SCOPUS databases

Figure 6 – Frequency, per journal, of publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction (2017-2022)



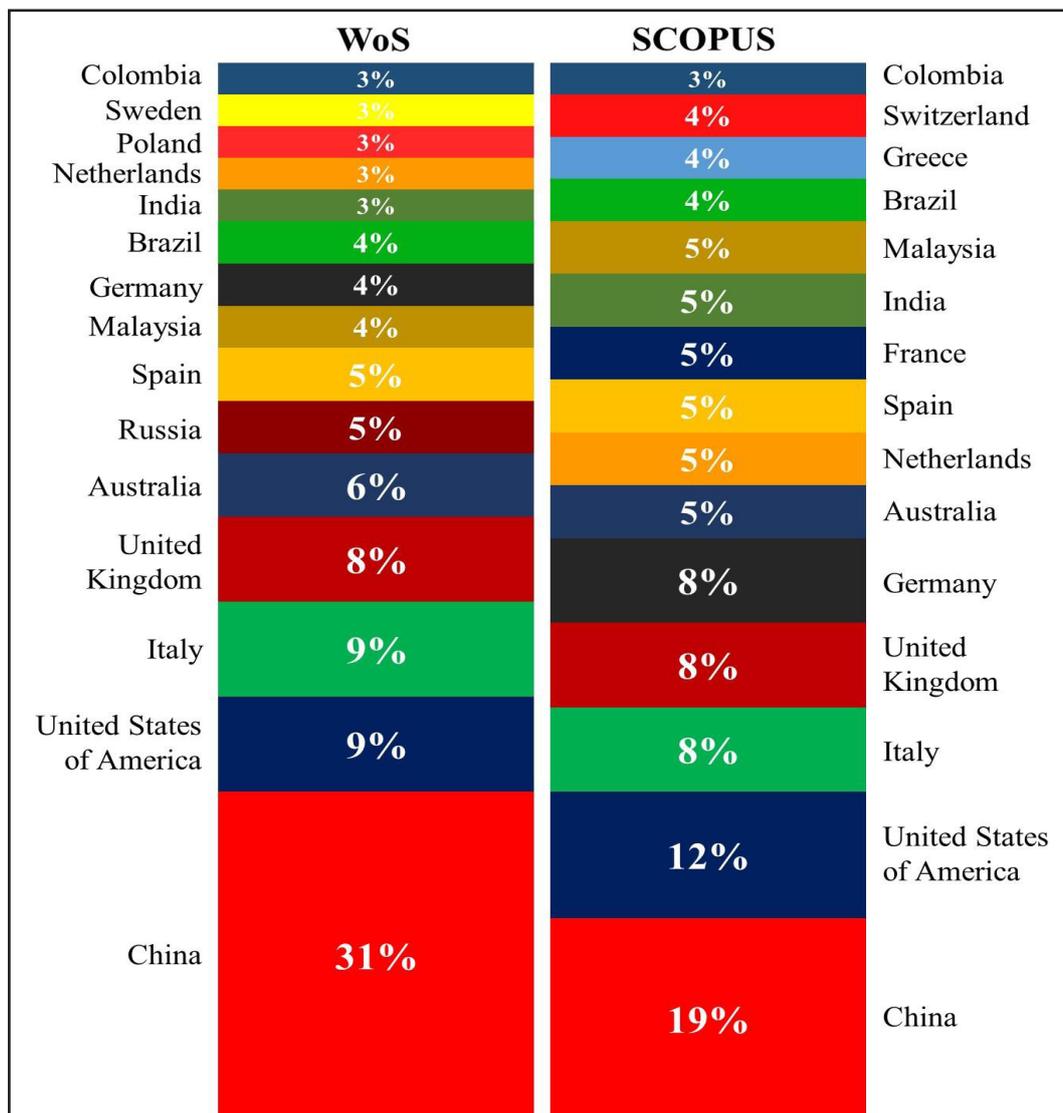
Source: elaborated by the author, based on the WOS and SCOPUS databases

There has been a significant increase in publications relating Environmental, Social and Governance practices, Sustainability and innovation in civil construction in the last 2 years, demonstrating the growing relevance of the topics in the academic context. However, there is a centralization of publications regarding these specific topics in few journals, such as Journal of Cleaner Production, Sustainability and Science of the Total Environmental, pointing out a gap to be filled by other high-impact journals so that the themes are more disseminated. In addition, it is noted fragmentation of the

topic, with the sum of publications in journals with a maximum of three publications representing more than 60% of the total. Regarding the authors who published the most, there was no significance in the results, with only three publications during the analyzed period.

Figure 7 shows a comparison of the WoS and SCOPUS databases regarding the number of publications, by country, producing the most publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction.

Figure 7 – Publications, by country, of publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction (2017-2022)



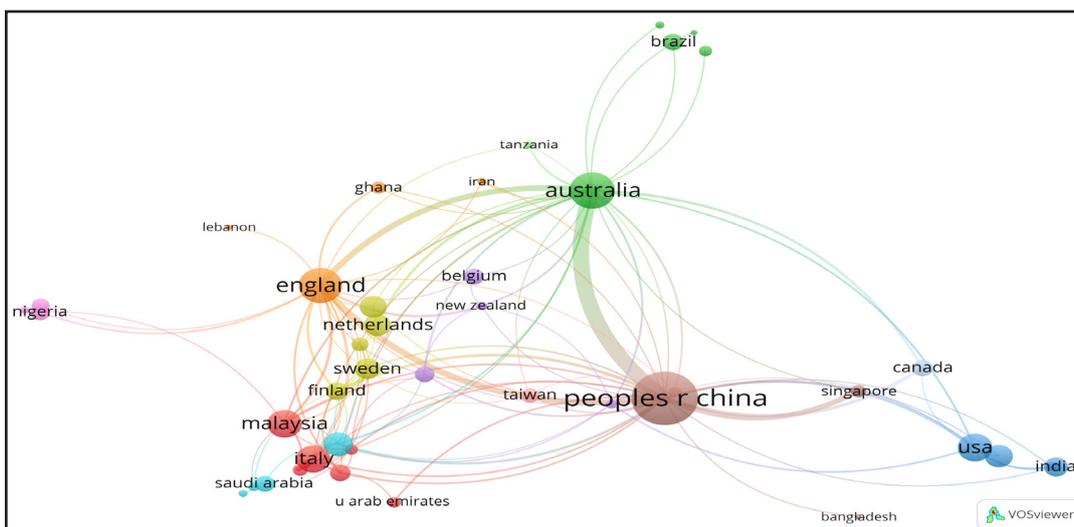
Source: elaborated by the author, based on the WOS and SCOPUS databases

Considering the 15 countries that are most published in each database, there is a predominance of China and the United States, followed by the United Kingdom and Italy, in both databases. Brazil ranks 12th in WoS and 10th in SCOPUS, with approximately 4% of publications.

The literature on Environmental, Social and Governance practices, Sustainability and innovation in civil construction is vast, comprehensive, and contemporary. Furthermore, the scope of the discussion on the themes is supported by the large number of countries (77) cited in publications in the WoS and SCOPUS databases.

It can be observed, in Figure 8, that 45 of the 77 countries have a connection network of citations in publications. These connections, especially between the most cited countries - China, Australia and England - corroborates the replicability of practices in different parts of the world, demonstrating a common interest in improving the performance of civil construction.

Figure 8 – Most cited Countries in publications on Environmental, Social and Governance practices, Sustainability and innovation in civil construction (2017-2022)



Source: elaborated by the author with the VOSviewer Software from the WOS and SCOPUS databases

Another highlight is the favorable condition of practices common to companies in the sector in several countries. Although each country has unique characteristics

that impact the civil construction industry, the publications found similarities in some practices, construction methods and sustainable and innovative materials used.

5.2 ESG practices and innovation in civil construction

Of the 488 publications found on ESG practices and innovation in civil construction, more than 200 include forms of sustainable housing from an environmental and social point of view, case studies showing the relationship between green buildings and financial performance, innovation practices presented in the daily construction, among others, presented in Table 1. In addition, more than 200 are about two major themes: the use of innovative and sustainable materials; construction methods directly in construction and renovation works. Regarding innovative and sustainable materials, several practices were studied and presented, as shown in Table 2.

Table 2 – Innovative and sustainable building materials presented in the publications (2017-2022)

Building materials	Relevant publications
Concrete made with recycled glass	(Abellán-García et al., 2019)
Roofs based on multilayer cement	(Angelotti et al., 2018)
Thirsty concrete capable of absorbing a large volume of water	(Atakara & Ramezani, 2020)
Materials based on natural fiber from <i>Phaseolus vulgaris</i>	(Babu et al., 2019)
Bricks based on marble paste and laminated steel scale	(Baghel et al., 2019)
Palm bark fly ash as asphalt concrete additives	(Chaira & Mawardi, 2019)
Wire-bent wood and glass composite elements	(Nicklisch et al., 2018)
Ceramic bricks made with olive pomace	(López-García et al., 2021)
Melt shop slag and blast furnace granulate as an alternative for fine aggregates	(Sudarshan et al., 2021)
Concrete beams with bamboo reinforcement to increase earthquake resistance	(Hidayat & Aldo, 2020)
Concrete embedded with e-waste	(Gajalakshmi, 2017)
Superabsorbent polymers in cementitious matrices with reduced carbon footprint	(Weinand, 2020)
Hemp-based sound-absorbing building materials	(Fernea et al., 2017)
Nano-silica as a concrete additive	(Pragadeeshwaran & Sattainathan Sharma, 2019)
Thermal insulating material made with residual fibers from peas	(Soto et al., 2020)
Structural magnesium oxide insulating panels	(P. Li et al., 2018)

Source: elaborated by the authors

As for innovative and sustainable construction methods, studies are exemplified, presented in Table 3, which propose conceptual, design, structural and technological alternatives.

Table 3 – Innovative and sustainable construction methods presented in the publications (2017-2022)

Construction methods	Relevant publications
Wood frame	(Toppinen et al., 2019; Viholainen et al., 2021)
Light steel framing	(Dosumu & Aigbavboa, 2018)
Drywall	(Imron et al., 2017)
Prefabricated/precast	(Liew, 2018; Tazikova et al., 2020)
Plastic bottle houses with the function of sealing blocks	(Adefila et al., 2020; Oyinlola et al., 2018)
Modular constructions	(Xu et al., 2020)
Green roofs	(Yu et al., 2017)
Bubble deck slabs with air bubbles	(Oukaili & Merie, 2018)
Smart homes	(Kassim et al., 2019; Paparella & Caini, 2018)

Source: elaborated by the authors

The construction industry is in a difficult situation to develop an economic system of producing low-cost housing, due to the ongoing COVID-19 pandemic, which has led to a crisis of shortages of building materials and instability. The price of some inputs, such as oil and steel, suffered an accelerated price increase in the international market, causing many countries, especially the less developed ones, to suffer an increase in the housing deficit (Ashiru & Anifowose, 2021). Based on this reality, the authors proposed the use of dry construction – a concept that encompasses more agile construction methods, such as steel framing – and concluded that construction time could be reduced by 70%, making the final value of residential construction cheaper.

On the use of light steel to improve the capacity for sustainable development in buildings, Dosumu and Aigbavboa (2018) investigated the level of knowledge, adoption and willingness to adopt the technique, in addition to assessing the benefits and challenges of the topic. Interviewing companies in the construction sector,

these authors conclude that there is room in the country to increase awareness and willingness to adopt projects with steel structures, but there are limiting barriers related to execution challenges, such as high initial cost and the need for skilled labor.

With regard to green building technologies, Darko et al. (2017) carried out a study to identify the significant problems associated with the adoption of so-called Green Building Technologies (GBT). According to these authors, the popularity of the topic depends on understanding the barriers to technology promotion, but also on the main factors and strategies that can bring advantages to companies. The main barriers found are the lack of knowledge and awareness, resistance to change and higher initial construction costs. The main factors or advantages of promoting technologies for green construction were greater energy efficiency, water savings and companies' image and reputation. As for the strategies, the most important were gaining experience on the cost-effectiveness of GBT and achieving greater market share after obtaining the green seal.

Combining factors such as the use of innovative and sustainable materials and construction methods with the sustainable renovation of buildings and a focus on energy efficiency, Killip et al. (2018) point out that energy consumption in buildings, especially in older ones, is a major contributor to global carbon dioxide emissions. Thus, these authors studied the association between the renovation of existing buildings - using technologies - with increased energy efficiency or on-site renewable energy generation. Their study shows that the concept of energy efficiency, from the point of view of technological renovation of buildings, needs to move from individual thinking and to a large scale. It demands an effort in academia to explore, through research, the role of the supply chain, i.e., manufacturers and distributors of technological components and materials, as well as government agencies that can assist in making them more affordable.

Table 4 – Publications about energy efficiency in homes and buildings (2017-2022)

Building materials	Relevant publications
A synthesized factor analysis on energy consumption, economy growth, and carbon emission of construction industry in China	(Lai et al., 2019)
Additive Manufacturing Integrated Energy-Enabling Innovative Solutions for Buildings of the Future	(Biswas et al., 2017)
An exploratory study of the South African concentrated solar power sector using the technological innovation systems framework	(Potts & Walwyn, 2020)
Cost and benefit analysis as a tool to support decisions on energetic streamlining in the green building sector	(Sgandurra et al., 2017)
Design and Construction of a Solar Energy Module for Optimizing Solar Energy Efficiency	(Tobias et al., 2020)
Energy consumption of hybrid smart water-filled glass (SWFG) building envelope	(Gutai & Kheybari, 2021)
Energy Savings and Sustainable Construction: Examining the Advantages of Nanotechnology	(Oke et al., 2017)
Factor space for the development of sustainable energy technologies in construction	(Myshovskaya et al., 2019)
How can life cycle thinking support sustainability of buildings? Investigating life cycle assessment applications for energy efficiency and environmental performance	(Ingrao et al., 2018)
Innovation and certification as the basis for the development of energy-efficient construction	(Trukhina et al., 2019)
Innovation Management in Polish Real Estate Developers in the Renewable Energy Sources Context	(Sitek & Tvaronaviciene, 2021)
Intelligence of LED towards innovative nanotechnologies in the efficiency of building envelopes	(Mocerino, 2019)
Key barriers to the implementation of energy-management strategies in building construction projects	(Enshassi et al., 2018)
Orchestrating households as collectives of participation in the distributed energy transition: New empirical and conceptual insights	(Skjolsvold et al., 2018)
Parallelism in energy production through interior architecture sustainable development	(Osama & Helaly, 2017)
Performing quantitative analyses towards sustainable business models in building energy renovation projects: Analytic process and case study	(Moschetti et al., 2018)
Proposal for efficient use of the green energy on the selected objects of the construction equipment	(Adamuščin et al., 2018)
Smart Lumini: A Smart Lighting System for Academic Environments Using IOT-Based Open-Source Hardware	(Gonzalez-Amarillo et al., 2020)
Technology Frontiers of Building-integrated Photovoltaics (BIPV): A Patent Co-citation Analysis	(Zhong et al., 2020)
The achievement, significance and future prospect of China's renewable energy initiative	(Sun, 2020)

Source: elaborated by the authors

In 20 publications, listed in Table 4, the concept of energy efficiency in homes and buildings was explored in different ways, generating examples of practices tested in different countries and regions such as South Africa, Australia, China, Colombia, Egypt, Slovakia, United States, Philippines, Italy, Norway, Palestine, Poland, Portugal and Russia and that can be replicated in other countries.

Other topics such as sustainable housing, ways to innovate in the day-to-day work, use of Building Information Modeling (BIM) technology, recycling and construction waste reduction, models for smart cities, environmental regulations for ESG practices in construction companies were addressed in the remaining publications.

6 CONCLUSIONS

The research aimed to analyze the evolution of the literature about ESG and innovation in civil construction, exploring and promoting the discussion of practices in the sector related to the environment and socioeconomic development of construction companies. In addition, we sought to explore what are the main subjects addressed in publications on the proposed topics.

A Systematic Review of the Literature was carried out and the results showed an increase in the importance of the topics in the academic area, translated into a constant growth in publications in recent years, considering the WoS and SCOPUS databases, and a more pronounced increase in 2020 and 2021, in both databases.

The results showed an Asian predominance in the publications, in relation to the most cited countries and to the authors and co-authors, with emphasis on countries such as China, Malaysia, Singapore and Taiwan. Regarding the green practices adopted by construction companies, more than 80 countries were represented with examples of innovation and sustainability in: construction methods and materials; clean energy; smart and sustainable home projects; recycling and reuse of materials, among others.

In relation to bibliographic coupling, networks of strong connections in clusters by countries and regions showed that authors of new publications tend to seek

publications from the same region as a reference. Even though civil construction practices can be replicated in different countries and regions, there is a common habit among researchers to base their work on local publications.

Regarding the number of publications, by country, in relation to ESG and innovation in civil construction, China predominates and the other 3 largest in both databases são USA, Italy and UK, while Brazil occupies only the 12th position in WoS and the 10th in the SCOPUS, representing approximately 4% of total publications about these topics.

The journals that published the most in the period on the researched topics were Journal of Cleaner Production, Sustainability and Science of the Total Environmental, but there are publications (approximately 63% in WoS and 53% in SCOPUS) in journals with only one or two publications. This may indicate that ESG and innovation in civil construction topics are scattered, in addition to showing that other journals are beginning to publish on these topics.

About the keywords most used in the analyzed publications, a mirroring of the WoS and SCOPUS databases was noted. In WoS, there was a greater use between 2019 and 2021 of terms focused on technology, optimization and processes, while terms such as environment, projects and sustainable strategies were more used in 2017 and 2018. In SCOPUS, a more concentrated use of keywords with technical engineering terms was identified in 2017 and 2018, such as steel structure, fiber reinforced materials and green chemistry. In later years, from 2019 to 2021, terms such as climate condition and environmental problems were more used.

As the discussion about ESG and innovation in civil construction was conducted in each database, between 2017 and 2021, in a different way, when it comes to keywords, it shows that the research, carried out in more than one database, becomes complementary. It also reveals an evolution of the themes in each one of them, since the publications maintained the themes, but with different approaches over time.

About the practices exemplified in the 488 publications found in the Systematic Literature Review, it is concluded that there is much to explore about replicable initiatives to improve ESG aspects and innovation in civil construction. It was also observed that some practices are more advanced, such as the use of prefabricated and wood framing, appearing in several publications, while others are more disruptive and require a greater number of trial-and-error tests.

This study has some limitations. First, the bibliometric analysis focused on the literature on practices in residential construction, without an assessment of other segments of civil construction. Secondly, the publications found show alternatives for builders to seek sustainable development, but there is no statistical study showing the effectiveness of the evidenced practices. Finally, the evidenced speed of the evolution of the discussion about ESG and innovation in the sector is highlighted, indicating that the same work carried out in this paper will have to, eventually, be redone.

In terms of practical implications, despite the restrictions above, this paper provides examples of innovative and sustainable practices in civil construction, in addition to mapping, by specific subjects, the volume of publications in the WoS and SCOPUS databases. In search of alternatives to keep civil construction constantly growing in a sustainable way, consuming fewer resources and generating less waste in their processes, civil construction companies have a vast collection in the literature, as demonstrated in this paper.

Being the purpose of this research to add to this vast and current discussion about ESG and innovation, addressing the relevance of these themes to civil construction through an SLR, the results obtained show an evident need for continuity of the discussion about these themes.

Given the discrepancies in citations and publications in relation to some countries and regions, which appear less in the Systematic Literature Review, while others such as China and the USA are more prominent, some questions arise in terms of further prospects. Is there a relationship between the country's level of development and the

level of implementation of ESG and innovation in civil construction? Countries with a higher level of implementation of the ESG concept actually have more publications with practices on this topic? Is innovation, when practiced, guided by the principles of sustainability? What are the biggest difficulties faced by construction companies in relation to the implementation of ESG and innovation practices? Are companies operating in more than one country or region able to replicate innovative and sustainable practices or are there restrictions?

These are pertinent questions, which can be explored with further studies. It would be important to apply new, more centralized surveys, for example, survey surveys with companies from specific countries to measure their ESG performance and innovation and, in addition, specific surveys with leading global construction companies.

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2. Development of hypotheses or research questions (empirical studies)	√	√	√	√
3. Development of theoretical propositions (theoretical work)	√	√		
4. Theoretical foundation / Literature review	√	√	√	√
5. Definition of methodological procedures		√	√	
6. Data collection	√	√		
7. Statistical analysis	√	√		
8. Analysis and interpretation of data	√	√		
9. Critical revision of the manuscript			√	√
10. Manuscript writing	√	√	√	√

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