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Review

Sustainability in the construction industry: A systematic review of the literature

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ABSTRACT

The construction industry is criticized for causing adverse impacts on the environment. To minimize these impacts, the industry has been seeking to introduce sustainable practices throughout its entire production chain. Therefore, the objective of this study is to run a quantitative bibliometric research through meta-analysis methodology and, consequently, to evaluate the articles used by qualitative methods in the area of sustainability in civil construction. For this, a search was carried out on the Web of Science. Thus, a set of keywords was used, followed by a filtering method, resulting in a review of 433 articles published in 18 years. VOSviewer software was used in the quantitative analysis of documents. The results demonstrated a lack of quantitative methodologies to assess sustainability in the civil construction industry. Thus, this research presents the evolution of studies, the main areas addressed, the main certifications and methodologies for environmental assessment, and the distribution of the on-site work stages in articles. This revealed the main contributions found in the literature, presenting the article's focus, being as main areas explored material, project management, sustainability assessment, and energy; the most used methodology (LCA) and environmental certification (LEED). It was seen that the social and economic pillars are less frequently tackled when compared to the environmental one. It was also perceived that most of the papers focus on the planning and execution stages of the on-site work, being necessary to develop more studies on operation and maintenance stages. These results serve as a source of reference for future research.

Contents

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1. Introduction

Sustainable construction has been increasing rapidly around the world in recent years due to resource reduction and so has been facing a number of challenges and problems from a managerial, strategic and operational perspective. In addition, the construction industry plays an important role in meeting society's needs by improving the quality of life (Hwang et al., 2017; Doan et al., 2017; (Alwan et al., 2017)). Nevertheless, this sector accounts for 35% of global CO_2 emissions and generates between 45 and 65% of the waste deposited in landfills. In addition, the construction sector and its associated activities produce a significant amount of harmful emissions, namely, about 30% of greenhouse gases on the planet due to operations during the construction process, 18% of these emissions are caused by transporting and processing construction materials (Zea Escamilla et al., 2016).

In this context, the relevance of the study of sustainability in the civil construction sector is evident since organizations are increasingly aware that guaranteeing a competitive advantage depends not only on achieving customer satisfaction based on low costs or the quality of the product or service offered. Customers expect companies to respect the environment, be ethical and demonstrate that they are socially responsible (Alencar et al., 2017).

Then, there is a need to explore sustainability in civil construction, being conducted in this study a systematic review of the literature (SRL). An SRL seeks to maximize the amount of information on how this topic has evolved; to show in what main journals papers on the topic have been published, and on what research areas; what the methodologies for assessing impacts on the environment and what certifications have been used; and how the focus of such articles have been framed; and what other criteria, if any, have been developed by the scientific community on this topic. Taking this approach led to identifying that studies on the construction industry and sustainability go hand-in-hand. However, there are no quantitative systematic studies on this subject that target classifying the main characteristics of studies published in the literature. Therefore, the relevance and the differential of this study concerning other systematic reviews are evident since this SRL brings together a variety and considerable volume of information collected from various articles. Therefore, this study sets out to make contributions to organizations, governments, and the general population, so that sustainable alternatives and a vision of the future will be drawn up, thereby ensuring the sustainability of systems used in the construction industry and by those who supply materials to it.

An analysis of the literature shows that a small number of studies have conducted an SRL on the construction sector, and these are as follows. Carlucci et al. (2018), set out to identify the main sources of uncertainty in the literature regarding adaptive thermal comfort models in built environments that used regular documentation applied to different climatic zones. As a result, several adaptive thermal comfort models have been integrated into several normative national and global comfort documents to elaborate buildings with lower energy consumption rates. Diaz Lozano Patino and Siegel (2018), presented an SRL of 49 articles dealing with internal environmental quality conditions in a social housing home. It sought to determine the concentrations of air pollutants, thermal comfort, and possible health effects in this dwelling, referring to sustainability. This paper encompassed the social pillar, focusing on the low-income population, buildings with several units, substantial presence of minorities and/or older people, and use of rent subsidies, making an analysis of retrofits for this population, to explore the process of designing and implementing improvements for the society. Ma et al. (2018) presented an SRL of papers that analyzed the human perspectives' dimensions to noise. Since people spend many hours in buildings, it was important to investigate acoustic influences. Their study also provided new knowledge for understanding human-environmental interactions and new alternatives for future construction projects; understanding the human perceptual dimensions of sounds is essential for acoustic environmental management, as it promotes the prediction of objective sound properties for subjective responses.

Other studies have investigated other aspects of this sector but did not carry out an SRL. For example, some studies explored environmental assessment methodologies in the context of civil construction (Carabaño et al., 2017; Chomkhamsri et al., 2017; Najjar et al., 2017). Other authors have published articles on the production of materials, their properties, and their use (del Río Merino et al., 2017; Macillo and Fiorino, 2017; Al-Jabri et al. 2017; Svajlenka and Kozloska, 2017). We also found that there are studies in the literature that focused on the production of residues; environmental indicators; green alternatives for construction; and the operational performance of on-site works with certifications (Alrashed et al., 2017; Fregonara et al., 2017; Ozcan Deniz, 2017) and others which discuss other developments on the subject.

Sustainability in the construction industry can help meet present and future generations' needs by conserving energy, water, and natural resources through reuse, recycling, innovative design, and minimizing waste and pollution. To do so, proactive measures are taken to reverse or minimize the negative impacts that construction activities have on the environment (Aigbavboa et al., 2017).

Therefore, this article sets out to analyze the literature on sustainability in the context of civil construction to identify information, data, evolution, characteristics, and relevant hypotheses that have been discussed in scientific articles, thereby providing an investigation into what has been and is still being developed by the scientific community. The aim was to cover as much information as possible on the subject, thus helping organizations, government, population, and guiding new research.

Thus, this review contributes to a broader understanding of sustainability in construction, offering technological, economic, social, and environmental benefits through a variety of information and tools. Additionally, it provides strategies to minimize the

environmental impacts of construction materials and project management, including questions on the main areas covered, methodologies worked, certifications used in recent years, and how they impact the sustainability pillars, thus helping models and methods for decision making. Therefore, this review is quite significant within the global context, aiming to increase interest in research and applications in the area.

This article is structured as follows: an introduction, which presents the scientific context, the relevance of the theme, the contributions of past studies, and this paper's objectives. Section 2 presents the methodology used and the stages of the SRL, and Section 3 presents the results, which are discussed in Section 4, which also summarizes the main contributions of this paper. Finally, Section 5 briefly presents the main conclusions and makes some recommendations for future studies.

2. Material and methods

This section discusses how this SRL on sustainability in the construction industry was carried out. The review was based on the quantitative methodology used by Seuring and Müller (2008), which presents four steps: collection, descriptive analysis, selection of categories, and evaluation of the material. This type of review uses methods that can be replicated to identify, select, and evaluate papers in the literature on the subject of research studied.

We searched for primary studies in the main collection of the Web of Science - Main Collection database (Thomson Reuters Scientific), using three sets of key-words identified by the authors during a brainstorming process. These consisted of search terms that were considered to be obligatory (O) for this study to collect the maximum amount of information following the scope defined; 3 search terms; a set of words related to sustainability (S), with 29 search terms; and a set of words related to civil construction (C), with 26 search terms, as shown in Table 1. It is important to note that these search terms were linked by the Boolean "and" logic, considering articles on this subject published between January 2000 and December 2017. The search continued until May 4, 2018. The terms were searched by topic, covering the title, abstract, and keywords of each article, to encompass the maximum amount of information in the database on this topic.

This search returned 1127 articles. Only articles from related areas were considered. Exclusion criteria were identified and adopted to refine the results (see Table 2).

After applying the filters mentioned by the exclusion criteria, 433 articles were obtained for analysis, as shown in Fig. 1.

After reading and selecting the articles, the meta-analysis was generated by VOSviewer tool containing information from the journals that published at least 30 papers and the data included authors, titles, keywords of the 433 documents. Thus, the maps were created based on data from the network, where the size of the circle is determined by the weight of the item and a particular parameter or cluster to which the item belongs and the lines represent the links between the terms (Eck and Waltman, 2017). Finally, qualitative analysis was carried out in order to elucidate issues in the field of civil construction and sustainability associated to framing the focus of the articles (materials, project management, models that assess sustainability), three pillars of sustainability model, stage of the construction works, works with certifications, environmental assessment methodologies.

3. Results

From the systematic literature review, some analyses were performed on the 433 articles selected. These articles were analyzed as to their general characteristics and so as to extract data on sustainability in civil construction in greater detail.

3.1. Quantitative and meta-analysis results

3.1.1. Frequency of the number of papers published per year

In view of all the criteria used to perform the SRL, the evolution of studies published in the area in the period covered by this study could be identified. It was also found that the number of published papers grew over time. There were especially sharp increases between 2014 and 2017, as shown in Fig. 2.

In the first 9 years (2000–2008), 37 papers were published, about 8.5% of the total, an average of 4.63 papers/year, which is a relatively low number when compared to 2009–2014, when 141 papers were published, 32.5% of the total, at an average that increased to 23 papers/year. There were steep increases in the

Table 1
Set of keywords.

Group	Keywords
O	Build* and Construct* and Sustain*
S	"Clean energy" or "Cleaner production" or "Climate change" or "Eco*" or "Eco-efficient" or "Economic" or "Energy" or "Environment*" or "Global warming" or "Green" or "Green seal" or "Greenhouse gases" or "Impact environmental" or "Natural resources" or "Recycl*" or "Renewable energy" or "Renewable resources" or "Reuse" or "Reverse logistic" or "Social" or "Socioeconomic" or "Socio-environmental" or "Sustain*" or "Sustainable business models" or "Sustainable development" or "Water reuse" or "Sustainable Certifications" or "Environmental Certifications"
C	"Acquisition" or "Post-Occupancy" or "BIM" or "Build*" or "Building waste" or "Civil Engineering" or "Concrete" or "Construction waste" or "Construc*" or "Construction industry" or "Demolition" or "Edifice" or "Construction Equipment" or "Housing*" or "Infrastructure" or "Maintenance" or "Building Materials" or "Construction Materials" or "Procurement" or "Reform" or "Sanitation" or "Supply chain" or "Water resources" or Wood or "plaster" or "Steel"

Table 2
Exclusion criteria.

Exclusion Criteria	Justification
C1: articles published (n) by journals with n < 3	Journals that just published up to two articles during the 18 years investigated in this literature review had their papers excluded, as they did not configure journals with the theme under their scope.
C2: articles written in any language other than English	English is considered a standard language in the scientific community, is considered the standard language by journals with high impact and global reach. Thus, studies that were not in English language were excluded.
C3: full text articles that are not available on the scientific basis (C3)	Papers that are only with their abstract available during the data collection period were excluded from the study.
C4: articles outside the scope of this research: Sustainability in the Construction Industry	Studies that did not include the sustainability area in the civil construction industry were excluded.

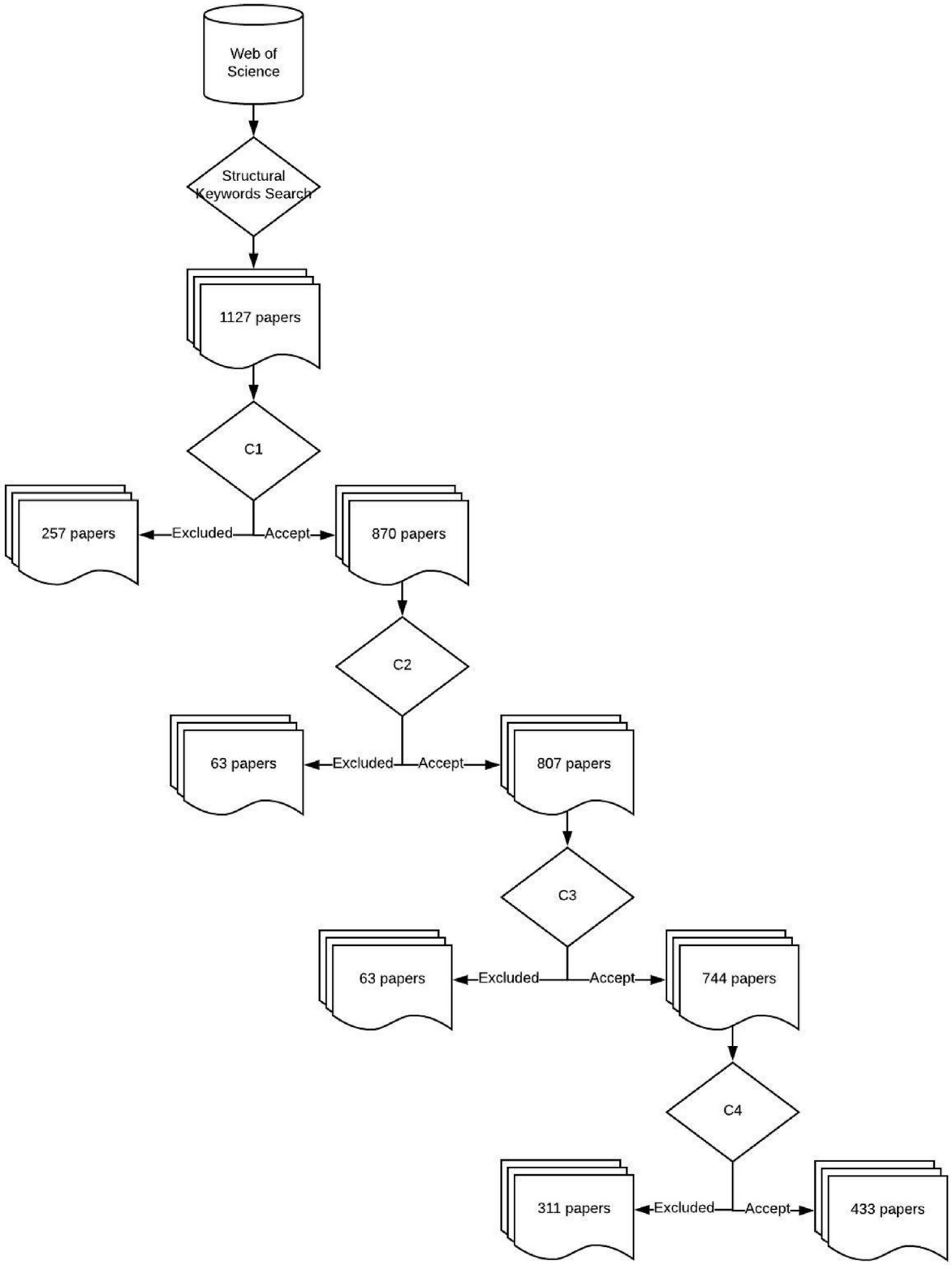

Fig. 1. Method for filtering to obtain the articles for the SRL.

number of papers published in both 2015 and 2016 which almost saw the total number of papers double in both of these years, while the 3-year period of 2014–2017 accounts for about 59% of the papers published from 2000 to 2017.

The increase in the number of articles can be justified by the growing interest in the construction sector's improvement strategies. For example, many papers highlighted the use of recycled products, waste management, selection of materials for sustainability management (Gangolells et al., 2014; Oyedele et al., 2014) since the construction industry is considered one of the sectors that

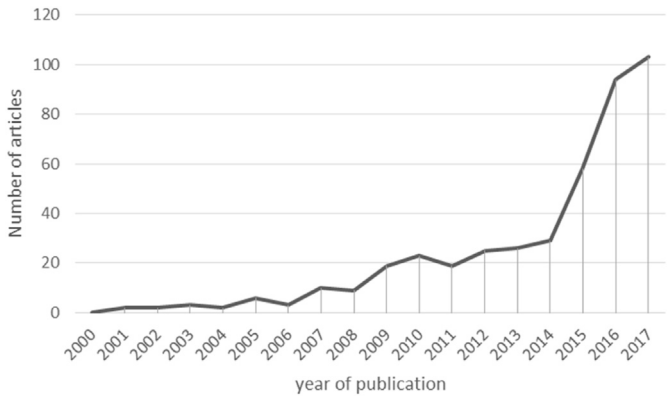

Fig. 2. Papers published between 2000 and 2017.

contribute negatively to aspects related to the environment, consuming renewable and non-renewable resources and is one of the largest producers of waste (Liu et al., 2014). Therefore, it is known that these issues have a high potential for global warming and greenhouse gases (GHG) emissions, from the design, construction, and operation until the disposal of waste after the ending of works in the construction site (Ng et al., 2013).

Besides, this sector seeks to reduce emissions of polluting gases (Kim and Chae, 2016; Mequignon et al., 2013). Another relevant issue observed is the increased use of the number of green protocols and environmental assessment methodologies, which can quantify the indirect and direct resources used in construction projects, to assess whether such work is sustainable or not and whether it has met the standards of environmental accounting conformities defined by the Green Building Council (GBC) (Onat et al., 2014). Finally, another point is that integration between sustainable measurement models and green classifications can become a standard practice in construction projects (Alshamrani et al., 2014).

Another important factor was that specific legislation for each market came into force. These new rules may have influenced the increase in the number of papers published since 2014, which mainly target the European and Asian markets, 34.12% and 31.37%, respectively.

There are strong pieces of evidence that explain the growth in the number of articles as from 2014. The first is that prior to then, in order to undertake work on a site, construction strategies did not consider either environmental sustainability or cleaner production. Thereafter, in order to reduce impacts and increase the performance of the process, alternative procedures were established, which targeted the overall efficiency of the process, thereby ensuring sustainability. In addition, it is important to emphasize that in general, the prevalence of published papers that deal with sustainability in the construction industry can be explained by the fact that many of these papers address construction in Europe and Asia and several countries on these continents had adhered to Agenda 21 as a plan of action for developing greater sustainability. These not only verified processes and strategies adopted for sustainable construction at the international, national and regional levels but also made commitments on reducing carbon emissions and pollutants (Al-Jebouri et al., 2017; Clarke, 2010; Tomovska and Radivojević, 2017).

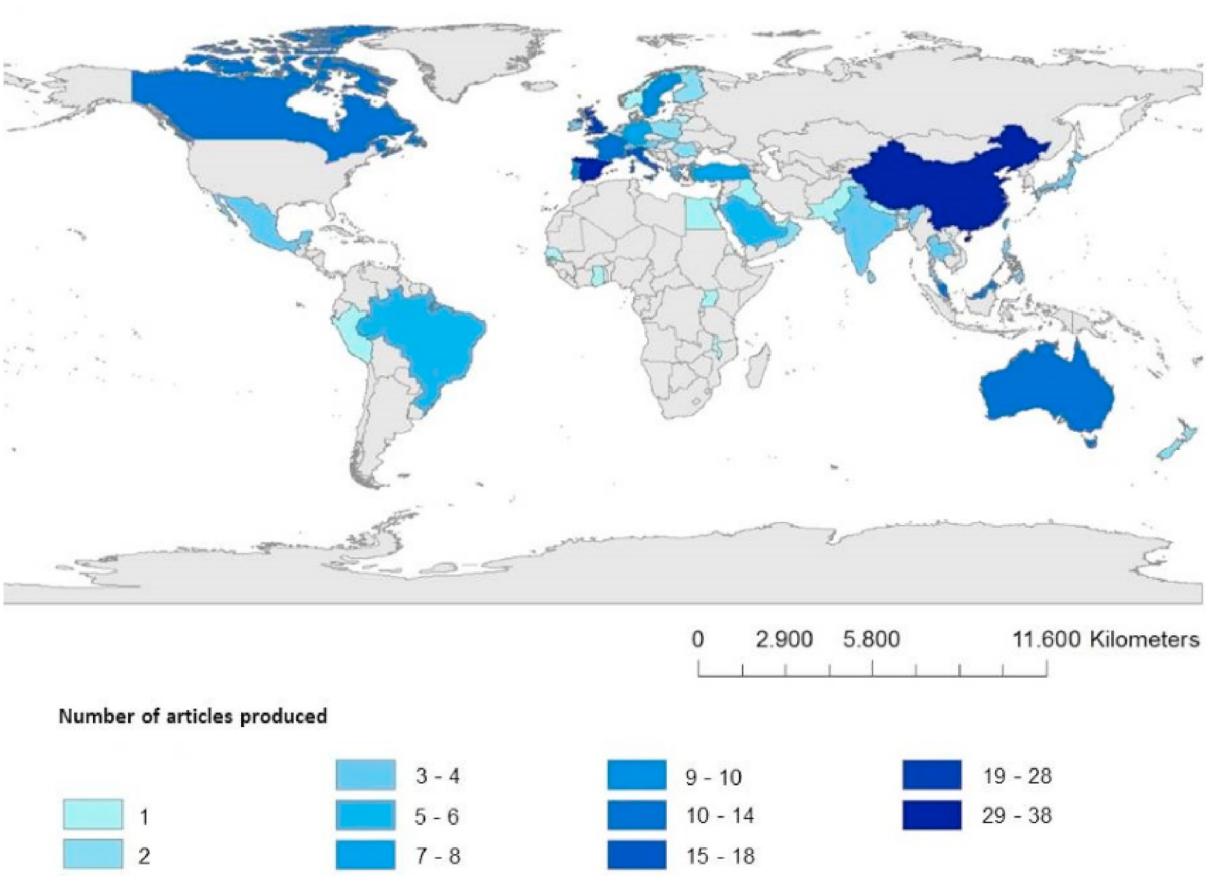

Fig. 3. Place of application of the studies.

Table 3
Main areas of the journals of the articles dealt with in the SRL.

Research Areas	Number of articles
Construction & Building Technology; Engineering	84
Engineering; Environmental Sciences & Ecology	64
Science & Technology - Other Topics; Engineering; Environmental Sciences & Ecology	61
Engineering	49
Construction & Building Technology	41
Construction & Building Technology; Engineering; Materials Science	37
Science & Technology - Other Topics; Environmental Sciences & Ecology	18
Science & Technology - Other Topics; Engineering	16
Environmental Sciences & Ecology; Public Administration; Urban Studies	14
Environmental Sciences & Ecology	11
Materials Science	8
Environmental Sciences & Ecology; Urban Studies	7
Science & Technology - Other Topics; Public Administration	5
Biodiversity & Conservation; Environmental Sciences & Ecology	4
Construction & Building Technology; Materials Science	4
Business & Economics	4
Construction & Building Technology; Engineering; Public, Environmental & Occupational Health	3
Engineering; Materials Science	2
Environmental Sciences & Ecology; Public, Environmental & Occupational Health	1
Total	433

Table 4
Impact factor of the four most cited journals.

Journal	Papers published	Impact factor	5-year impact factor
Building and Environment	56	4.053	4.464
Journal of Cleaner Production	45	5.715	6.207
Construction and Building Materials	31	3.485	4.039
Resources Conservation and Recycling	30	5.120	5.228

Table 5
Journals and their respective *Sum of number of citations and* h-index.

Journal	Sum of number of citations	h-index
Building and Environment	2147	28
Journal of Cleaner Production	1360	24
Construction and Building Materials	1593	21
Resources Conservation and Recycling	1360	24

Fig. 3 shows the main regions in which studies were applied and draws attention to the distribution of these among the continents.

European regulation no. 305/2011 on the market for construction products lays down environmental declarations of products as tools for assessing environmental impacts and that these should include the entire life cycle of a product, thereby creating new targets for reducing CO_2 emissions that need to be achieved by 2020. The corresponding standard in the European Community is EN 15804 D.I.N, 2012 plus A1: 2013, which lays down rules for categories of construction products (EN 15804, 2012).

Some countries in Asia are ranked in the CCPI (Climate Change Performance Index) such as in critical situations in carbon emissions, thus leading to plans to reduce these levels having been drawn up (Tatari and Kucukvar, 2011). Malaysia, for example, stated that it would reduce carbon intensity by 40% by 2020 and has, in recent years, been encouraging studies that target these countries (Bin Marsono and Balasbaneh, 2015).

3.1.2. Frequency of main areas of the journals

The articles analyzed are distributed over 67 journals, 6 of which account for 47% of the papers published. Undertaking this research made it possible to identify the main journals that addressed the civil engineering sector and sustainability. The main research areas of the journals of the articles dealt with in the SRL refer to those presented in the Web of Science database (Table 3). They directly reflect the search for new construction techniques, new technologies, and materials to reduce pollutants, reduce the use of energy and water, and manage solid waste generated throughout the entire life cycle of activities in this industry.

Overall, these are the pieces of evidence that show that the papers found in the literature and their respective areas of research tend towards the areas of construction, materials science, technologies and ecology.

This research also drew attention to the impact factor of the scientific articles published in the journals which had published at least 30 papers (Table 4). In addition, this paper presents the main research areas found in the studies according to the Web of Science - Main Collection database, which point towards areas of Technology in the Construction of buildings, Engineering, Ecology and Materials (See Table 3).

Following the same line, that is, analyzing journals with at least 30 publications, it was possible to collect information such as sum of number of citations, h-index, that value based on a list of classified publications in descending order based on number of publications (see Table 5).

3.1.3. Keywords analysis and main institutions regions analysis

Since sustainability in civil construction is studied in large communities with a long history, it is challenging to manually conduct our holistic review. Instead, we leveraged bibliographical data, i.e., keywords and citations, and used VOSviewer, a freely available text mining software, to generate bibliometric maps of scientific fields.

The information was extracted and exported by the database itself, which provides data in a format compatible with the VOSviewer software results. To carry out this analysis, the researchers adopted stages of choices in the software platform, as the decisions

determine the options displayed by VOSviwer, where the terms are identified in the text data through a natural language processing algorithm (Jan and Ludo, 2010), to compile the information and generate the network, allowing the visualization of clusters, with common characteristics on the map. Also, the tool itself uses the data normalization methods, ensuring the consistency of the results desired by the researchers. VOSviewer builds maps based on a co-occurrence matrix, and this software supports the technique of grouping distance-based maps, that is, maps in which the distance between items reflects the strength of their relationship. For example, the smaller distances between the items say that it has a stronger relationship, presenting the identification of groups of related items (Jan and Ludo, 2010).

Using these search terms, we downloaded the publication information, i.e., title, abstract, author, citation, publication year, as a tab-delimited text file, suitable for further processing with VOSviewer.

We employed two analysis techniques to generate our results. The first method is a keyword analysis, distributed into four clusters that were published at least 30 articles, in the time range and scope of this research and results in scientific landscapes that we use to analyze historic development and recent trends. It is important to highlight that the type of analysis was co-occurrence and the unit of analysis was all key word. As a second method, we used the bibliographic coupling information such type of analysis and the countries for unit of analysis.

Finally, the scientific landscape of civil construction and sustainability was generated. The size and color of the circle represents the frequency of occurrence and cluster type of the individual keyword, respectively. Lastly, the distance between the keywords is representative of their relative co-occurrence, e.g., two keywords that are close to each other co-occur more frequently, whereas a large distance between two keywords indicates that they do not co-occur. Fig. 4 illustrates the network of links between main keywords, distributed into four clusters that were published at least 30 articles, in the time range and scope of this research. It is important to highlight that the type of analysis was co-occurrence and the unit of analysis was all key word.

The VOSViewer software assigns different colors to the different types of clusters, and each color of the cluster is determined by its weight/significance. Therefore, the colors vary from yellow (very low score), blue (low score) to green (average score), to red (high score) (Eck and Waltman, 2017).

In Figs. 4 and 5, the circle's size and color represent the frequency of occurrence and the type of cluster of the individual keyword, respectively. Finally, the distance between keywords is represented by their relative co-occurrence; for example, two keywords next to each other co-occur more frequently, while a large distance between two keywords indicates that they do not occur simultaneously.

We can infer from that, that in the published studies, the focus has been on sustainability, energy performance, LCA environmental assessment methodology and pollutant gas emissions, where there are direct relationships with the theme of construction materials and waste (Fig. 4), emphasizing the increase of global gas emissions from the effect caused by the construction industry. Due to the availability of resources, construction projects must promote the reduction of greenhouse gas emissions. Also, except for the blue cluster, the two clusters are close together, and the keywords construction and sustainability are located in the center of the three clusters.

Table 6 summarizes these clusters. We labeled each cluster manually (Research Topic) based on the observed keywords in each cluster, where all groups there was relationship with Sustainability term. Thus, Table 6 presents the clusters' panorama, grouped by co-occurrences of the documents' keywords. For example, in the red cluster, keywords related to green methodologies and energy systems coexisted and, consequently, we named the Environmental Assessment Methodologies and energy performance group. Similarly, Sustainable Construction, Construction material, and Wood, respectively.

This analysis provides an opportunity to combine research

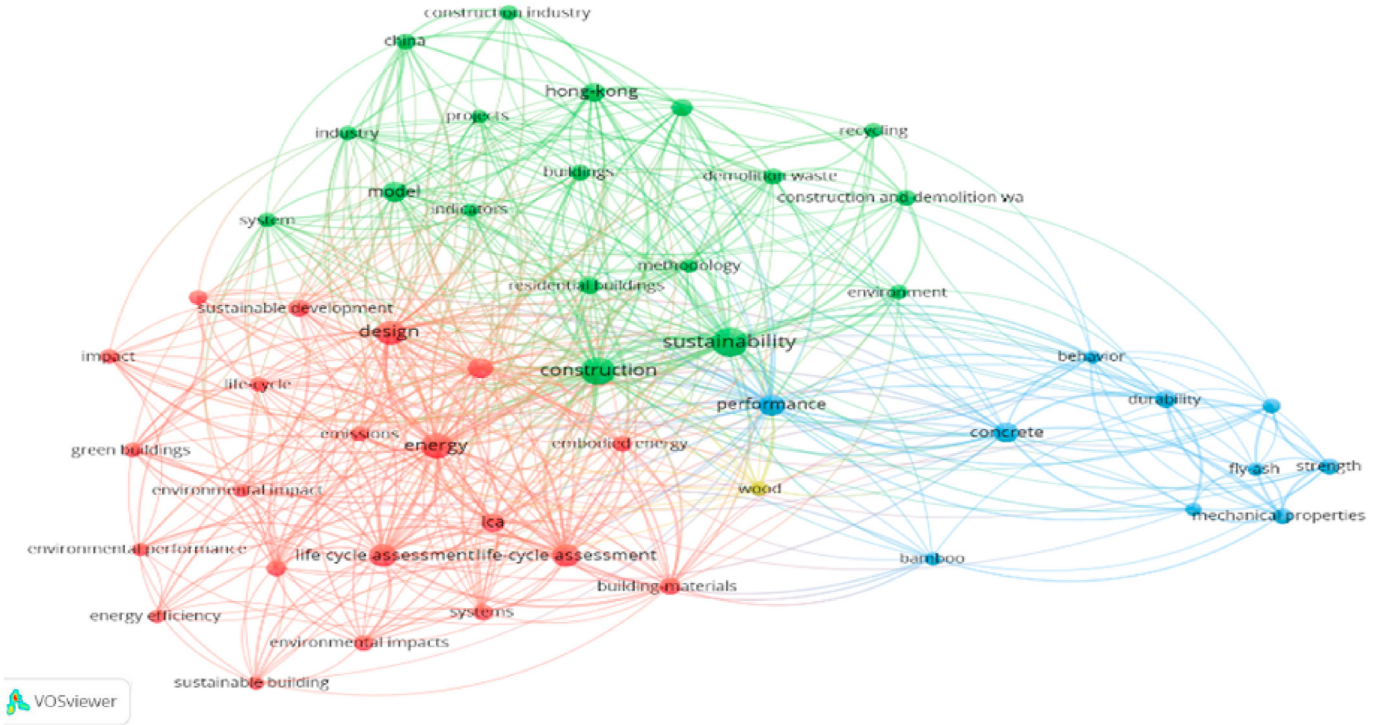

Fig. 4. Keywords used in articles.

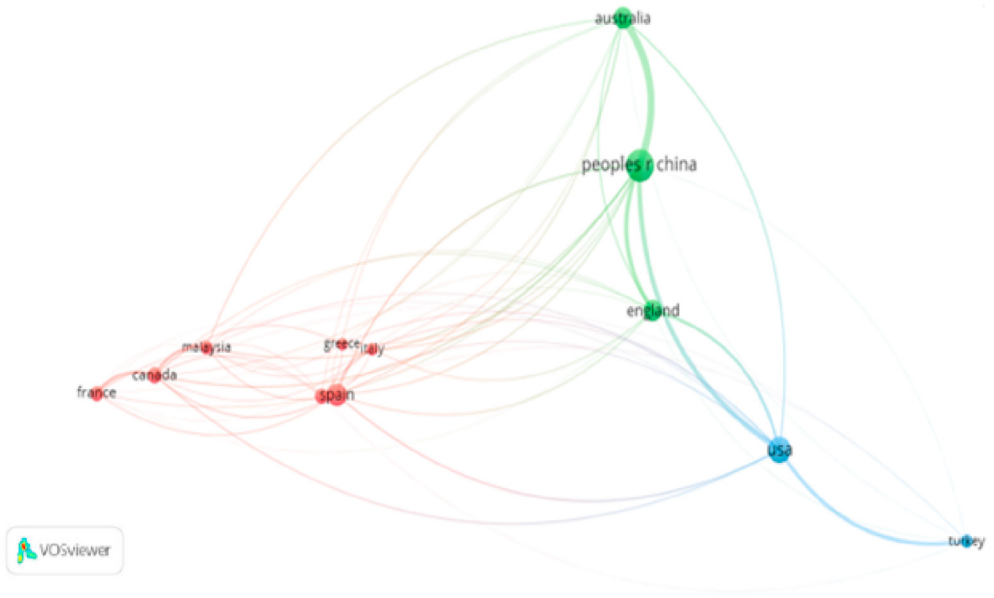

Fig. 5. Countries that concentrate the research in the area.

Table 6
Keyword clustering result by the publications.

Cluster Color	Research Topic	Observed keywords	Number of Documents
Red	Environmental Assessment Methodologies, and Energy	Design, energy, life cycle assessement	49
Green	Sustainable Construction	Construction, sustainability, residential buildings	62
Blue	Construction material	Performance, concrete, behaviour	28
Yellow	Wood	Wood	21

related to construction materials and environmental assessment methodologies. These fields complement each other, helping to measure the environment's negative environmental burden through the waste generated by construction inputs. In the yellow cluster, the keyword wood is present in several documents, reinforcing its central location within the generated bibliometric map, located between LCA and performance. Previously published studies have worked on reducing polluting gases by using green methodologies and indicators integrated with construction materials accepted by law and following green requirements and practices.

The 433 articles were analyzed using VOSviewer software to create maps in which the most important studies were represented by circles and their links by lines. In order to show he main regions of institutions of studies, type of analysis was bibliographic coupling and the unit of analysis was countries, for the first inquiry. It can be seen that was distributed into three clusters and the most important region was peoples China, with 33 documents and 872 citations, follow by Australia, with 15 documents and 240 citations (Fig. 5). We can see that the distance between the red and green clusters is greater than any other distance. This indicates that the regions of the research institutions that addressed the theme for sustainability and construction are the ones that least co-occur compared to the others. This type of analysis was carried out to identify the main regions, presenting what the studies in each area address and identifying partnerships between institutions, so that, in a future study, to know the entities that have already established and generated results positive in the academic community.

3.2. Qualitative results

In the present study, we only analyzed articles indexed in the Web of Science database and in order to reduce losses, and compile a larger data set the qualitative phase the articles were done.

The previous section's analysis supported the conduction and directing of each discussing issue in the qualitative analysis, guided by the identification of the keywords most used by the articles and the research topics. They are framing the article's focus, three pillars of sustainability, the construction works, works with certification, and environmental assessment methodologies.

Thus, it was initially discussed framing the article's focus to explore the main dimensions in the main areas explored in the studies over the years.

Then they were analyzed as to the pillars of sustainability. It is important to know how the three pillars of sustainability have been explored in the studies conducted, along with the themes that have been investigated, which have been paying more attention, which needs more studies to be developed, and how changes in legislation and pressures from impacted on this point.

Regarding the stages of construction works, it was verified by the keywords that design has appeared in many articles. Although it is not the phase with the largest number of studies, it is the stage that exerts a greater influence concerning sustainability in construction, in which the decision-making regarding the sustainability implementation in the other stages will be taken. The focus of the articles on project management also highlights this importance. Thus, it is essential to detach how studies address sustainability within the construction stages to guide the development

and improvement of construction sustainability.

The main certifications found in the articles were another point studied, as the certifications can serve as tools to achieve environmental sustainability in civil construction, improve the performance of construction projects, as they reduce the negative impacts on the environment, ensuring standardization among construction products.

Also, environmental assessment methodologies were studied, as there are several environmental assessment tools, with different purposes, including in their calculation the total assessment of the system, considering the impacts associated with a construction site, thus offering measurable support for construction projects, which seek to ensure competitive advantage in the market, being ethical, social and environmentally conscious and economical.

3.2.1. *Framing the focus of the articles*

Sustainability has been explored in different areas within the construction industry. In order to better understand how this action occurs, the articles were broken down into the different areas of activity over the years, as shown in Fig. 6.

The main areas covered in the articles are materials, business management and evaluation models. It is noted that in recent years other areas have also been explored, thereby reflecting possible market demands and legislative issues as addressed in Section 3.1.

3.2.1.1. Material. With regard to the framing of the papers, it was noted that a large number of them, 182 articles, about 42% of the total, focus on research on construction materials. Among the materials most cited in this research are concrete, steel, cement and wood. A large number of papers focus on construction materials as main topics approached (Zavadskas et al., 2018). With the market increase for searching products with ecological and environmental characteristics, building materials are the main issue, as they are valued at the same price compared to standard products (Kozicki et al., 2018).

Selecting the most appropriate construction materials is essential when seeking to produce more sustainable buildings, since the materials used are directly linked to the impacts they have on buildings, both with respect to quality, durability, solidity, cost and finish of the construction, as well as to the quantity of CO_2 consumed throughout the life cycle of buildings (Zea Escamilla and Habert, 2014).

It is important to keep in mind the energy incorporated, hence the CO_2 consumed, into each phase of a building's life cycle, to understand the importance of materials throughout each phase. CO_2 is produced in every stage of the life cycle, from the phases of manufacture, transportation and construction to the building operation, the maintenance phase after the completion and demolition of the building. The primary phase of CO_2 production is the phase of operating and maintaining buildings. This is because the most significant amount of CO_2 emitted results from producing energy from the operation of equipment, such as the systems for heating, ventilation and air conditioning, and the operational phase of a building is the longest period of its total life cycle (Oh et al., 2017).

Carreiras (2015) states that various aspects should be taken into account when choosing building materials such as toxicity, built-in energy, waste reuse and durability. In terms of durability, the technical requirements address issues of stability and resistance to chemical, physical and biological agents such as light, heat, moisture, microorganisms, and salts. As for thermal comfort, the focus is on the insulating strength of heat and sound, the strength of waterproofing power and the absence of harmful elements. As to aesthetic issues, what need to be observed are the aspect of the material already placed in the finish of the construction works and the design of the building (Erlandsson and Levin, 2004).

For this reason, many studies have been oriented towards this theme, whether this concerns seeking new construction products that are environmentally more "correct" or looking for direct substitutes. In addition, secondary raw materials are being incorporated or construction or other production processes are being re-used or re-cycled. Factors that are taken into account when selecting materials include that they are available locally; they need little processing; their level of toxicity; they show potential for being recyclable; they are products which are culturally accepted and are suitable for self-construction (EN 15804, 2012).

3.2.1.2. Project management. Another point that stands out among ways that the papers are framed is that project management comes 2nd in the number of papers for one topic; there are 111 such papers, 26% of the total. This is because the insertion of terms related to sustainability in construction projects has brought about several challenges, many of which are linked to the general management issues of these projects (project management), mainly in relation to stakeholder management, waste management, contract management and decision-making issues on various matters (Fig. 7).

Some papers report the importance of stakeholder management in sustainability projects, since the success of the project is directly related to the degree of satisfaction of those involved and that everyone understands the objectives of the project, since these can be conflicting when they are compared to the traditional view.

The second most frequently addressed area of management in the papers is waste management. Ding et al. (2016) sounded the alert about the pressure that the large amount of construction and demolition waste puts on urban and regional sustainable development, which is why waste management has become an urgent

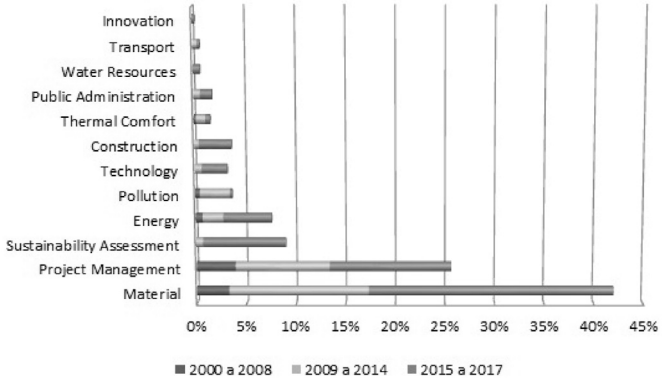

Fig. 6. Main areas dealt with in the articles by periods of time.

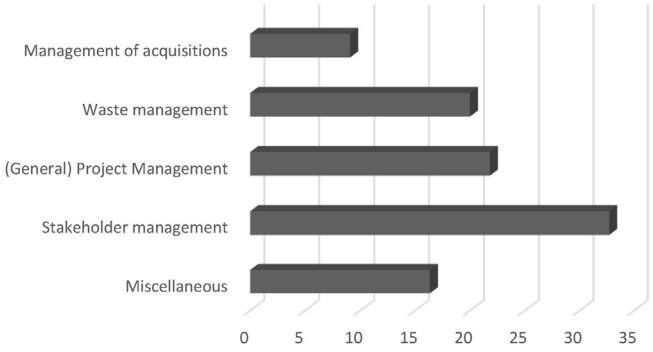

Fig. 7. Distribution of project management areas in the papers of the SRL.

issue. Marrero et al. (2017) stated that a good waste management plan is needed in construction projects to minimize the amount of construction and demolition waste. The construction method, design size, type of construction, method of storing materials, human error and technical problems are the main factors affecting the generation of waste from buildings that have been newly built.

Another relevant point within management is procurement management, since there are some barriers such as the knowledge of those involved on the types of products and services specific to green building and the difficulty in finding green suppliers, since the market still has to be regulated and public policies to encourage growth in the number of companies that offer products and services of this new philosophy still need to be made, thereby reducing the total cost of the operation.

Wong et al. (2016) argued that factors such as public regulatory changes and market mechanisms need to facilitate improvements in sustainable developments in the construction industry. Yan (2015) states that more comprehensive standards and government policies that lead to creating a positive market environment are critical to sustainable developments in the construction and construction material sectors. This need for more sustainable products, projects and construction processes has been perceived by international organizations and government policies that now promote new standards for sustainability in the construction industry, including requirements for functional, technical, environmental, social and economic performance to be at given satisfactory levels.

3.2.1.3. Sustainability assessment. The third most discussed point in the articles is new ways of assessing sustainability in projects, on which there 39 papers. These models were created by combining already existing environmental assessment methodologies, and factors addressed in environmental certifications. These models search for gaps in existing models and seek to address these gaps by finding solutions that best fit specific conditions, such as legislation issues, market requirements, and so on. Therefore, what is essential is that the professionals of the whole productive chain have adequate technical knowledge and tools that are adequate for day-to-day activities so that these professionals can carry out objective evaluations of this area of the market.

3.2.1.4. Energy. The energy aspect was the fourth question explored with 33 documents. It is possible to observe that this aspect is close to Sustainability Assessment since the construction industry consumes many resources and produces negative impacts on the environment. Hence, the fierce search for minimizing the negative burden is a challenge for everyone. Therefore, environmental assessment systems and green protocols play an important role, ensuring that sustainable practices are carried out, which is directly related to the consumption of energy spent on construction projects (Baglivo et al., 2014a; Chokor et al., 2016). Therefore, works that include sustainable tools and methodologies guarantee greater energy efficiency, thermal comfort, and occupants' satisfaction.

3.2.2. Three pillars of sustainability

Sustainability is composed by the three main pillars, Environmental, Social and Economic ones; nevertheless, many countries don't cover all dimensions. Then, each country and/or region need to identify the purpose of sustainable development for them.

Based on the findings, only 35,3% of the papers, 151 articles, address all three pillars, most studies, 165 articles, 37,9%, focused only on the environmental pillar, since this is the one that is most addressed due to the legal aspects, in addition to which it is this pillar that has the greatest appeal at the market level, and is, therefore, which has the most number of studies.

According to Raut and Gomez (2016); Tomovska and Radivojević (2017); Arslan et al. (2017), currently there are many reasons to focus on the environmental dimension, since many countries and organizations are adopting technologies, sustainable materials, clean and efficient processes, environmental protection, renewables, with the objective of reducing environmental impacts, reusing and incorporating new materials and of meeting society's current and future needs. Therefore, these actions may justify contemporary construction strategies and practices in terms of the environmental pillar since it is the one that the articles most address. This can be explained because the economic pillar refers to the financial consequences of the company's actions for the stakeholders; the social pillar to the part played by maintaining and improving the system with regard to rights and responsibilities; and the environmental pillar addresses how best to conserve and manage natural resources (Little et al., 2016).

Therefore, based on these possible concepts of the environmental dimensions, organizations, public policies and society tend to manage a strategy that is appropriately aligned with the objective of sustainability, thereby seeking to minimize the environmental impacts of their activities. Fig. 8 gives a graphic representation of the publications on the three pillars.

3.2.3. Stage of the construction works

Another of the main tasks that make up a project consists of undertaking the four stages. During the SRL, an analysis was made of the relationship between the papers on sustainability and the stage of the construction works (Fig. 9). The life cycle of a project concerns the sequential time distribution, which usually are: definition, planning, execution and closure (Van den Ende, 2015). In civil construction, these stages are: Planning, execution, operation and maintenance, demolition, and in some construction works, before demolition, the building is remodeled. This is called retrofit

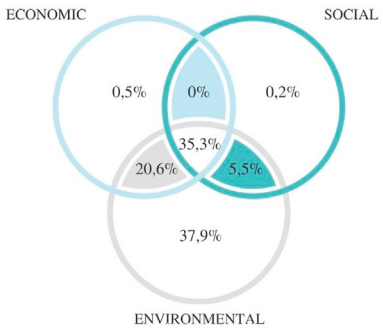

Fig. 8. Venn diagram of the sustainability pillars.

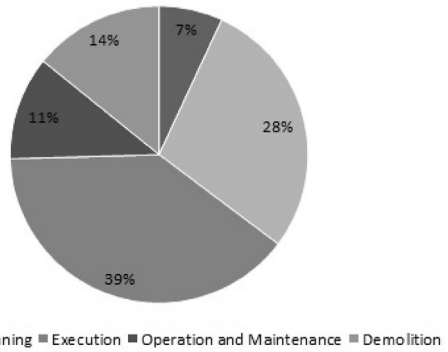

Fig. 9. Distribution of papers in the different stages of work on a construction site.

Table 7
Main certifications found in the papers.

Main types of Certification	%	Definition
LEED	45%	The classification system of Leadership in Energy and Environmental Design (LEED) of the US Green Building Council (USGBC) seeks to recognize buildings designed to achieve superior performance in a number of areas, including energy consumption and internal environmental quality (Chokor et al., 2016).
BREEAM	15%	The Environmental Assessment Method of the Building Research Establishment (BRE) uses internationally recognized performance measurement measures, applied from a wide range of categories and assessment criteria (Ilhan and Yaman, 2016).
ISO	9%	International Organization for Standardization: ISO 14001: aims to obtain correct environmental performance in organizations and to implement environmental management systems (Wang, 2014). ISO 14040 and ISO 14044: they target the phases of defining the objective and scope and analyzing the inventory of the life cycle (Trussoni et al., 2015). ISO 21929–1: This describes and provides guidelines for the development of sustainability indicators related to buildings and defines the aspects of buildings to be considered when developing systems of sustainability indicators (Castro et al., 2017).
OTHERS	31%	Comprehensive Assessment System for Building Environmental Efficiency (CASBEE): This certification has as a central component, the calculation of the building of environmental efficiency, based on performance. It considers some parameters, such as Indoor environment, Quality of Service, Outdoor Environment on Site, Energy, Resources & Materials and therefore, it is possible to classify from Japanese construction compliance (Ueda, 2012). Sustainable Building Tool (SBTool - international) is considered a generic framework, which aims to develop a rating system to evaluate the performance of buildings; for this, it is necessary to adapt it to each region/country that wants to evaluate (Alyami et al., 2015). Passive House: It originates from the German standard "Passivhaus," which appeared to guarantee thermal comfort and the energy efficiency. Its general principle is energy optimization of all components in a building to improve integration between inhabitants and energy efficiency (Foster et al., 2016). ITACA Protocol (Institute for Innovation and Transparency of Contracts and Environmental Sustainability): The Italian Association adopted the Sustainable Building Method (SB Method). The ITACA Protocol was prepared, which encourages the reuse of materials and or the use of already recycled inputs. (Baglivo et al., 2014b). Green Building Index (GBI): it assesses the relationship between the environment and construction projects' performance in Malaysia. It aims to achieve and incorporate ecological issues related to criteria such as energy efficiency, internal environmental quality, sustainable management, water efficiency, inputs and innovation. There are a total of points accumulated according to the criteria, so the buildings can be classified in three categories (platinum, gold, silver) and certified (Chong et al., 2017).

(Alba-Rodríguez et al., 2017; Castro et al., 2017).

Most parts of the studies (169 works) were carried out during the execution of the projects, with 39% of the total of the studies (material with 16%; project management with 10%; others with 13%), while 130 papers, 30% of the total, were conducted during the planning stages. These numbers reflect the articles' frames: when materials are selected, and project management is directly linked to the planning and execution stages of a construction site. In these steps, all decisions related to the project are taken and carried out sequentially.

3.2.4. Works with certifications

The review of the literature revealed that organizations are concerned with minimizing the environmental impacts caused by construction works in the civil construction sector, due to the excessive use of natural resources and energy, the production of wastes and causing pollution (Chokor et al., 2016). This has led to the search for environmental certification programs, which help to guide the management of projects and construction works at commercial and residential sites, and even infrastructure works, thereby generating benefits such as thermal comfort, lighting levels, water efficiency, tidiness, maintenance and well-being (El Asmar et al., 2014; Fisk et al., 2011; Issa et al., 2011).

By examining the studies selected, the main certifications were found, as shown in Table 7. LEED certification which was mentioned in 45% of the papers published was the most prevalent, then BREEAM in 15% and ISO in 9% of them. The other fourteen certifications (CASBEE, SBTool, Building Standard, Eco Housing, Estidama, GB, GBI, GBL-ASGB, GRIHA, GSAS, HQE, ITACA, Living Building Challenge and Passive House) accounted for 31% found in the studies.

Another important consideration is that of the 433 articles, only 47 approached and explored some type of certification on the construction works (Fig. 10) and this can be justified by the impact of the initial cost to the organization/owner. In addition, it is important to highlight that several studies have investigated in an integrated way more than one type of certification, as for example in the papers by Alyami et al. (2015), Camara et al. (2016), Hasik et al. (2017), Heravi et al. (2017), Awadh (2017).

3.2.5. Environmental assessment methodologies

According to Meex et al. (2018), the focus of sustainable construction is widening and this can be justified on account of national and international regulations and incentives, the purpose of which are to reduce the demand for natural resources, raw materials and energy, and to increase the performance of a building. Therefore, it is important to implement tools that quantify sustainability in the various phases of a construction works in order to promote maximum efficiency throughout the process, thereby achieving the social, environmental and economic dimensions.

Therefore, this study identified the main methodologies of environmental assessment that are inserted in the context of civil construction. It is important to note that of the 433 articles

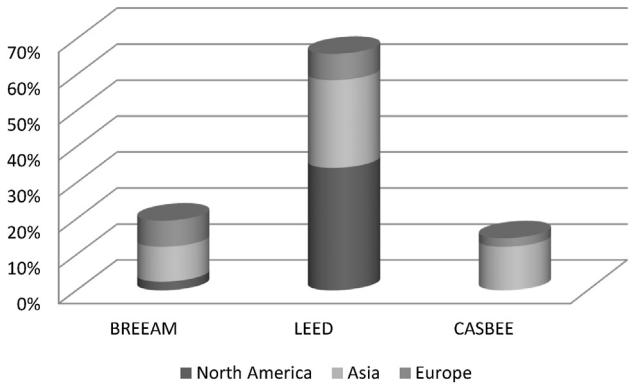

Fig. 10. List of papers with certification versus continental location.

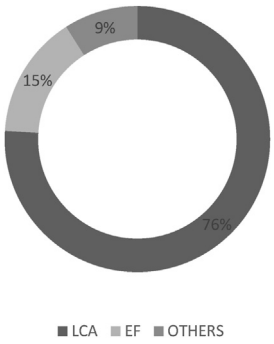

Fig. 11. Main environmental methodologies found in the papers.

analyzed, more than 10 types of environmental measurement tools were identified in 139 of these articles.

Fig. 11 represents the frequency of occurrence of the environmental measurement tools in the articles, highlighting LCA (Life Cycle Assessment), with 76%, which is considered the most adequate and objective evaluation method for quantifying the following: the consumption of energy and resources; the emission and generation of waste; and the environmental impacts of a building throughout its life cycle (Reza et al., 2013). Next comes Footprint (EF), which is an indicator that can be used to trace the consumption of terrestrial or biotic resources, the carbon-based residues of human populations (McBain et al., 2018). Another characteristic of this indicator is that it increases as more urbanization takes place. Moreover, 40%–50% of global emissions of greenhouse gases come from buildings (Ramesh et al., 2010).

The other tools, such as SEAM (Saudi Environmental Assessment Method), EcoInvent, quality of social life, Life Cycle Cost (LCC) represent only 9% of the papers and can be found in Ueda (2012), Vialle et al. (2015), Karatas and El-Rayes (2015), Kovacic et al. (2015) and in other studies. It is important to highlight that these tools also aim to assess and quantify the environmental load and sustainability of elements that can be found in the construction context.

LCA methodology appeared in several works dealing with construction materials, since it is a technique to evaluate the possible environmental aspects associated to a product. It is important to highlight the range of studies involving cement; in general they deal with the use of the material to assess the environmental performance and impact. It has also been found that cement production is primarily responsible for a environmental impact related for the global electricity consumption required as part of the industrial process, the outflows of re-use components and materials for recycling. There are also articles that have calculated the environmental, human health and socioeconomic effects of productive processes on construction materials, analyzing human health damage, ecosystem quality, and resource depletion (Cao et al., 2015; Igliński and Buczkowski, 2017; Moretti et al., 2017; Moretti and Caro, 2017).

4. Discussion

This section highlights some gaps and the most significant results of this review of the literature on sustainability in the context of civil construction. The following evidence is presented:

The area of materials is the sphere that is studied most in the context of this SRL articles. This can be justified because civil construction materials that are considered permanent or auxiliary generate greater environmental impacts. Therefore, they are the main focus of these papers (Ferreiro-Cabello et al., 2016).

This is also reflected in the range of articles that have explored and applied the LCA environmental assessment methodology, thus justifying the assertion that it is the most used. In other words, this is because it provides support in the civil construction sector and is applied efficiently for construction materials since this methodology can consider physical and chemical properties, volume, dimension, and the useful life of the components.

Based on the findings, as most articles focus on materials, it is important to invest in more research on materials aligned with the LCA, and provide prior information for companies to choose which material will be used consciously and which ones are appropriate in their processes.

Among the certifications explored in the articles, LEED was the most used because this classification system focuses to a greater extent on producing green buildings that are sustainable, more efficient and economical. It explicitly sets out to reduce pollution, wastes, the consumption of energy and impacts on Nature and human health by making more rational use of water, resources and energy, and by selecting the most appropriate materials and equipment (Gelowitz and McArthur, 2018). Then, our findings address significant implications for the use of LEED certification to support the management of resources that can be used to reduce environmental impacts.

Our findings also presented the stakeholder management as the managerial area most addressed in the articles investigated. This is because several people and/or organizations are involved in a construction project. The diversity of the nature of the stakeholders makes their management essential for the success of a project and for minimizing the negative impacts that potential conflicts of interest may generate. Therefore, finding a point of agreement between the different interests of the Stakeholders involved (contractor, organizations and clients) is essential in the search for a balance that satisfies all stakeholders (Hu et al., 2014; Tan et al., 2015). No studies were found in the literature investigated that identified the stakeholders' needs and preferences regarding prioritizing sustainable actions for the construction in different stages of construction works. Then, studies involving group decisions could be developed.

With regard to the pillars, the social and the economic ones are the least explored by the papers included in this SRL. The environmental pillar appeals strongly to the market, in addition to meeting political pressures, which encourages studies on this sector to be undertaken, which is not so for the other pillars. The social pillar is directly linked to users' perception or secondary criteria of the production process, such as employees' well-being (Karakhan and Gambatese, 2017). The economic aspect is also dealt with less frequently in these papers. Still, it is not so low when considering its integrated analysis with the environmental pillar or environmental and social. Thus, there is a need to develop studies in the social pillar sphere since it constitutes an aspect that is not very explored in the literature and even not known by the companies of the construction sector.

Regarding the stages of construction, in general, sustainable construction works have a higher initial cost, which would be "compensated" for by lower costs to the end user in the operational and maintenance phase when the building is used, but these depend a great deal on the users taking advantage of these correctly and on the observation period for this being sufficiently long, which either makes such studies unfeasible or to this line of research being attractive to only a few researchers (Adams et al., 2017; Yang et al., 2016). These criteria of correct use by the users and a long period of observation, during the operation and maintenance stage, make this stage, after retrofit, the least observed by the papers in this SRL (Feese et al., 2015; Vialle et al., 2015).

While some researchers explored the execution phase, a small proportion of works focused on sustainable development in the

operation and maintenance stage. For example, Chiang et al. (2016) evaluated green buildings' maintenance, aiming to integrate economic, social, and environmental issues for a Chinese city. Another study by Chiang et al. (2015) highlighted how existing buildings could be improved from green materials, contributing to the environmental pillar. Finally, the absence of work in the operation and maintenance stage may be related to factors such as cultural aspects associated with Building-maintenance decisions, because depending on the building location, there is a philosophy of carrying out maintenance actions focused only on specific parameters as the useful life of building inputs and systems. Additionally, the lack of studies focused on the operation and maintenance stage is also due to the long time spent collecting data and the participation of all those involved. Thus, it is necessary to develop research that investigates the maintenance stage, aiming at using alternative materials, reducing costs and carbon emissions, guaranteeing ideal green technologies for the environment, and the socio-economic dimension of ensuring that efficiency of maintenance activities is associated with building longevity.

Due to the emission of polluting gases produced by the construction industry, this research identified the need for a more significant number of studies regarding the adoption of green techniques and practices. Studies related to environmental assessment methodologies in the construction industry were analyzed, revealing the LCA methodology's greater use. However, the LCA and some environmental assessment methods do not consider in more detail the amount of solar energy present in the resources used in the study environment (Chen et al., 2017). In this context, a method verified in the literature is Emergy Analysis (EmA), a tool that analyzes a production system's inputs, considering thermodynamics principles. In the context of civil construction, EmA is understood as the total amount of available energy needed, directly and indirectly, to produce a building or an infrastructure. Thus, it is possible to develop quantitative indicators, which can be applied in different study contexts (Pang et al., 2015). In conclusion, there is an absence of more in-depth research on tools such as EmA, possibly due to the unavailability of information for applying the tools, making this a challenge for the civil construction sector.

5. Conclusions

The environmental impact caused by the construction industry is striking. Therefore, sustainability practices have been sought in recent years throughout the chain in this industry. To highlight these practices and trace the evolution of the studies in the different areas, a systematic review of the literature was carried out for the period between 2000 and 2017. The search was carried out on the scientific database Web of Science and followed pre-established criteria. After applying filtering methods, the search resulted in 433 papers. The analysis was conducted in three phases: quantitative analysis, meta-analysis, where the articles were filtered and clustered for bibliometric analysis, and qualitative analysis.

The growth in the number of studies in this area was noticed, especially between 2014 and 2017. The papers were classified by the area into which they were framed, and this showed that the area of materials and project management were the topics that had received the greatest attention. The distribution between the pillars was also observed, and this showed that the environmental pillar was the one most dealt with.

Other important matters that the SRL revealed are to have quantified the main certifications used in construction projects: LEED being the one most commonly found in the papers. The main environmental methodologies addressed in the studies were LCA and EF.

This work has brought together information on the main papers published on sustainability and civil engineering topics in the last 18 years, thus helping researchers to understand the evolution of the papers, the main areas covered, and the environmental methodologies and certifications dealt with. Therefore this SRL serves as a framework for future studies. The observations in this study provide insights for exploring several areas.

The study has some limitations. The findings are restricted to the taxonomy used, papers published from 2000 to 2018 available in the Web of Science, and journals that published at least 3 articles within this research scope. Finally, this research focused on works that approached sustainability in the construction industry and papers published only in English. Such aspects may cause changes in the number of articles related to the aspects evaluated in this work, such as certifications and locations, with country-specific certifications, among other aspects.

These results reveal some opportunities for future research studies, such as i) new sustainability assessment models that focus on the materials area; ii) studies focusing on stakeholders' identification and management regarding their needs and preferences related to project sustainable aspects; iii) studies that explore social issues, since it is the pillar of sustainability that has received the least attention in recent years; iv) studies focusing on the stages of operation and maintenance, which has been little explored, according to the studies investigated; v) studies that propose quantitative methodologies to assess sustainability in the civil construction industry.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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