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Review

Sustainable construction management: A systematic review of the literature with meta-analysis

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A R T I C L E I N F O

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A B S T R A C T

In addition to creating value and jobs, the construction industry uses a considerable amount of resources with severe consequences for the environment. Therefore, its implications should be reduced, especially since this industry has opportunity to reduce economic, environmental and social impacts. Once mitigating impacts is such an important matter for the construction industry, a systematic review of the literature has been run in order to investigate studies on the quantitative methodologies of sustainability in construction. This paper presents a review of over 2,600 papers on the topic. Mixed methods were applied for bibliometry, with Preferred Reporting Items for Systematic Reviews and Meta-analysis methodology to conduct a quantitative bibliometric search and subsequently assess the articles included using qualitative methods. These studies were subdivided into three groups: sustainability in construction, environmental aspects, and others. VOSviewer software was used in the quantitative analysis of documents, institutions and the most referenced journals. The results demonstrated that the first articles related to the topic of sustainability in construction were published in 1993 and that among the studies found in Web of Science only 2.54% used quantitative methodologies to assess the sustainability of the construction industry.

Contents

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1. Introduction

The construction industry is one of the largest sectors and despite creating value and jobs, it also uses a considerable amount of resources, with consequent impacts on socioeconomic and environmental conditions as stated by the International Organization for Standardization (ISO 15392, 2008; ISO 21929, 2011). Since construction is a personalized non-repetitive activity, it requires special attention (Rumane, 2017). Difficulties in reconciling the need for accelerated economic growth with sustainability are significant dilemmas in developing countries (Hosseini et al., 2018). Construction projects in developing countries have profound impacts on sustainability (Banihashemi et al., 2017). As such, it is important to minimize material and energy consumption, reuse and recycle materials and promote human satisfaction (Sinha et al., 2013). ISO 15392 (2008) underscores that the construction industry has excellent opportunities to improve its economic, environmental and social impacts. In this respect, sustainable projects may be an alternative in mitigating environmental impacts (Hernández-Moreno and De Hoyos-Martínez, 2010).

The Eco-Management and Audit Scheme (EMAS, 2001) defines the environmental aspect as an element of the activities, products or services of an organization that can interact with the environment. Despite the need for organizations to identify environmental aspects, irrespective of adopting a formal environmental management system (Johnston et al., 2000), the aspects were frequently confused and their identification compromised (Zobel and Burman, 2004). As such, when these aspects are not rigorously identified, they cause unmapped changes in the environment and promote negative impacts that affect the images of organizations (Murphy and Nahod, 2017). ISO 14004 (2007) underscores that there is no single approach to identifying environmental aspects, but the following can be considered: emissions to air; releases to water or land, use of raw materials and natural resources, local/community environmental issues; energy use; emitted energy (vibration); waste and by-products; and physical attributes.

There is no consensus in the literature with respect to identifying environmental aspects caused by construction industry activities, varying in terms of products, construction processes, documentation and researcher experience. Authors have used different techniques and identified several environmental aspects. For example, Gangolells et al. (2009) cited greenhouse gas emissions, volatile organic compounds and chlorofluorocarbon emissions in addition to the effects on biodiversity; Chen et al. (2004, 2000) disregarded release to water bodies in their research; Tam et al. (2004) considered soil alterations and the effects of ecological impacts on vegetation. The only consensus in the literature is related to the environmental impact of the construction industry, which has been criticized for being unsustainable (Yu et al., 2018). According to Teh et al. (2018), alternatives and practices should be explored in order to reduce the environmental impacts. The environmental aspects suggested by ISO 14004 (2007) were adopted in the present study.

Although there are bibliometric reviews on sustainability in the construction industry, no studies using a holistic approach were identified; rather, they emphasized sustainability assessment methodologies and each of the environmental aspects. As such, the present study aimed to make a systematic review of the literature in the field of Sustainable Construction Management classifying the studies into qualitative or quantitative research approach, discussing the advances in the quantitative methodologies of sustainability in the construction industry and presenting the state of the art in the field and as well as the gaps verified in the literature, which yet is a very small proportion of this literature (2.54%) and represents a very fertile field for research. The investigation is divided into five stages: introduction, where the history of construction management, environmental aspects and impacts is presented, stage two, which establishes systematic review methods to quantify and qualify the information and, finally, the results, discussion and conclusions are presented.

2. Material and methods

This article is a literature review in the area of sustainable construction management. This analysis was conducted in three phases, as shown in Fig. 1: quantitative analysis, a stage of meta-analysis where the articles are filtered and clustered for manual bibliometric and VOSviewer analysis, and in the last stage, qualitative analysis was carried out, where two different activities were performed, the first aimed at "construction industry sustainability" articles and the second, analysis of the results obtained with VOSviewer software.

Mixed methodology was used for the literature review and bibliometric analysis. Pluye and Hong (2014) reported that mixed methods combine quantitative and qualitative techniques as well as the numbers and explanations that they validate. Mixing research paradigms allows multiple levels and perspectives, in addition to combining the development of theories and empirical assessment (Gough, 2015). Since multidisciplinary and interdisciplinary topics discussing sustainability require multiple prospection, this methodology was selected to investigate sustainability and construction management.

2.1. Quantitative method

The articles analyzed were extracted from the Web of Science database covering the period between 1945 and December 31, 2018. The words used in the searches were *Construction management and Sustainab**, with the Boolean term* in the word sustainability, aimed at broadening the searches to include different

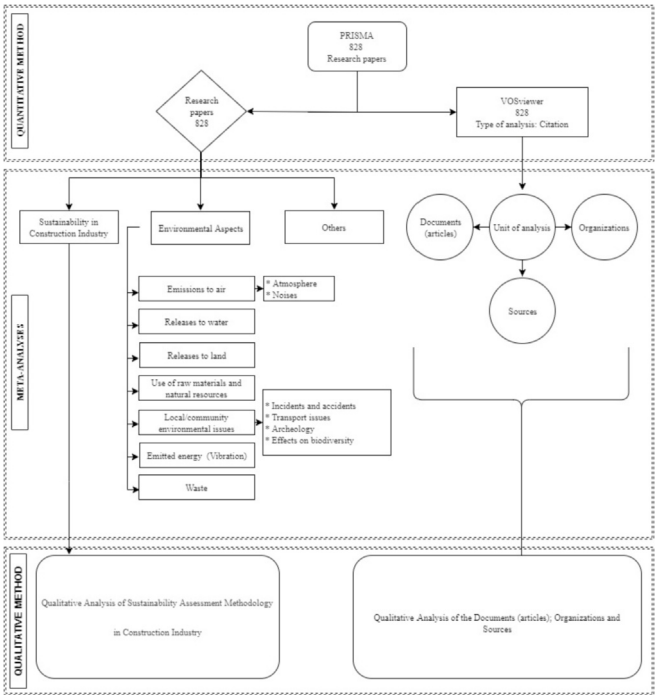

Fig. 1. Mixed Methodology
Source: The authors.

suffixes. A total of 2,655 articles were found. Although the database includes studies since 1945, the first article related to this topic was only published in 1993. In order to determine how the articles fit into the context of this research, filters that followed Preferred Reporting Items for Systematic Reviews and Meta-Analysis methodology (PRISMA) were established (Moher et al., 2010). The activities considered in each of the phases of this quantitative analysis are presented in Fig. 2.

The article extraction process, according to PRISMA methodology, is divided into four phases: (1st) Identification; (2nd) Selection; (3rd) Eligibility; and (4th) Inclusion (Moher et al., 2010). In the identification phase, keywords and complementary words were used in the Web of Science database, in which all the articles identified were extracted for the second phase (selection). The following filters were used in the second phase: English language, peer-reviewed and type of article. In the third phase (eligibility), titles and abstracts were read, and articles whose content was directly related to the topic and within the area of management, construction and sustainability were selected, excluding all others. In the fourth phase (inclusion), 828 articles were included for analysis.

2.2. Meta-analysis

Meta-analysis was based on a table containing information that included the order number (first or second), journal, year of publication, authors, titles and abstracts for the 828 articles. Three groups were created to distribute the articles. The first group ("construction industry and sustainability") contained articles that discussed the following topics: environmental management system in the construction industry; identification and assessment of environmental aspects; sustainable construction; environmental performance indicators; environmental tools and certifications in the construction industry. Articles selected for the second group were those on the seven environmental aspects established by ISO 14004 (2007). These aspects and their components are presented in Fig. 1. The third group, denominated "others", was created to include articles that seemed to be within the scope of this research in the initial assessment, but were eventually eliminated following in-depth analysis.

The 828 articles were analyzed using VOSviewer software to create maps in which the most important studies were represented by circles and their links by lines. The maps made it possible to identify the most referenced articles, as well as the journals that focused on construction management and sustainability and the institutions that conducted the research.

VOSviewer is used to create maps based on network data, where the size of the circle is determined by the weight of the item, that is, the greater the weight, the larger the circle and its source (Eck and Waltman, 2018). The color determines the cluster to which the item belongs, the lines between the circles represent the links, and the distance between the circles indicates the strength of the relationship between the terms analyzed. Analysis was conducted according to the number of referenced articles, journals and institutions.

2.3. Qualitative methods

Pluye and Hong (2014) reported that qualitative methods lead to empirical discoveries that theoretically explain the contributions of published articles. As such, qualitative analyses were adopted to elucidate questions from fields of knowledge of construction management and sustainability related to the development of quantitative sustainability methods.

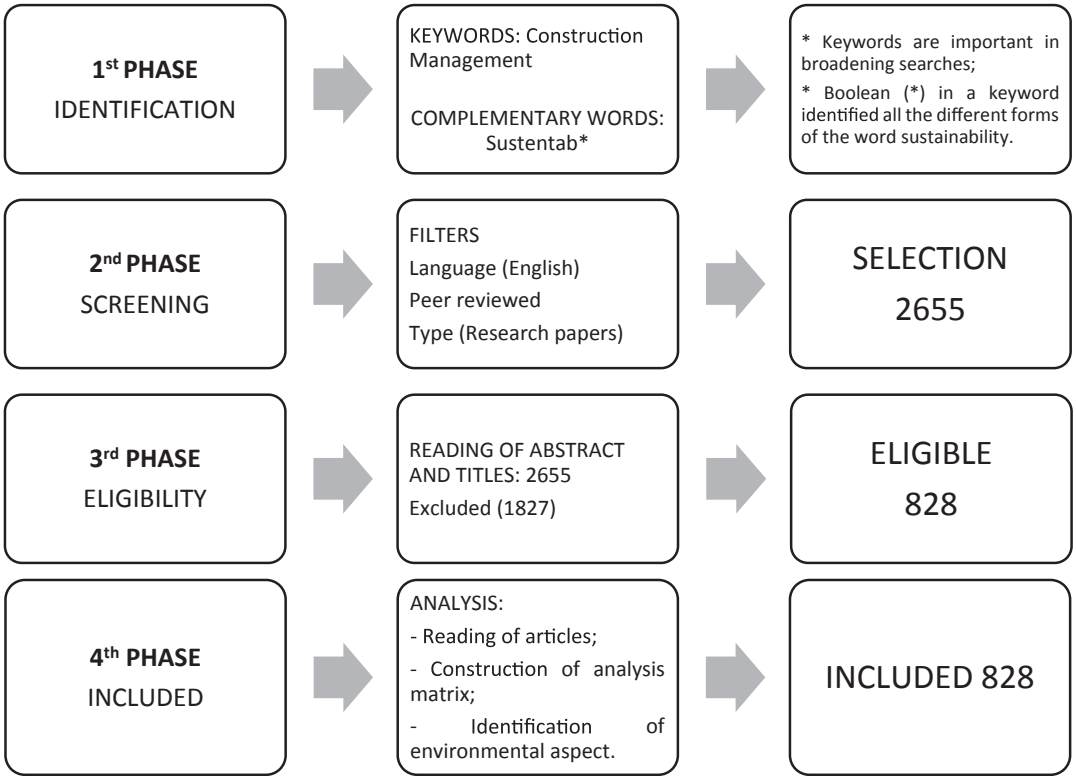

Fig. 2. Flowchart of the quantitative methodology phases
Source: The authors.

Two different analyses were conducted to qualify the articles. In the first, the content explored by sustainability in the construction industry articles was investigated, and studies that used methodologies that assessed the sustainability of construction projects were analyzed. For more in-depth analysis of these methodologies, bibliographic references from the articles discovered in this review were analyzed, including those that applied sustainability assessment methodologies. The second analysis involved a detailed assessment of the maps created using the VOSviewer software tool.

3. Results

3.1. General standards

Fig. 3 shows the distribution of articles related to sustainability in the construction industry over time. The oldest article was published in 1993 and up to 2005, no significant growth in the number of studies on the topic was observed. According to Kaminski (2013), the initial effort to develop an international standard for environmental management occurred at the 1992 United Nations Conference on Environment and Development, the same year that the British Standards Institution (BSI) published the British Standard (BS) 7750 (1992), the first standard for environmental management systems in the world. ISO 14001, based on BS 7750 (1992), and published in 1996, contained requirements for implementing an environmental management system in organizations, and a significant growth in the number of studies on the construction industry occurred only ten years after its publication. According to Wells (1993), the guidelines provide recommendations for managing environmental performance and establishing environmental policies aimed at complying with legislation. The number of articles has risen with the implementation of guidelines, regulations, laws and international treaties around the world since the 1990s.

3.2. Distribution of the three groups of articles

3.2.1. Results of "sustainability of construction industry" articles

A total of 97.46% of the studies were exploratory and only 2.54% of the articles were related to the quantitative assessment of sustainability in the construction industry. This spectrum agrees with that presented by Chen et al. (2005), who analyzed the databases of the American Society of Civil Engineering and Compendex Ei, finding that only 2% of the articles used quantitative methods in the environmental management of the construction industry.

The "sustainability in the construction industry" group included 341 articles on a host of topics, such as the environmental management system in the construction industry; identification and assessment of environmental aspects during the life cycle of construction products; sustainable construction; indicators of environmental performance; environmental tools and certifications in the construction industry.

Studies linked to proposals for developing quantitative methodologies to assess environmental aspects and/or sustainability in the construction industry were analyzed, revealing a clear divide. While some researchers explored the infrastructure sector (roads, bridges, megaprojects, urban development), others investigated the real estate industry (multi- and single-family dwellings, commercial buildings).

Nine studies focused on the development of quantitative sustainability assessment methodologies in infrastructure projects. Li et al. (2009) developed a system of 52 indicators of sustainable urban development for a Chinese city, represented via a full permutation polygon of "n" sides. Fernández-Sanchez and Rodríguez-López (2010) developed a methodology to identify, classify and prioritize the indicators of sustainability based on risk management standards. Krajangsri and Pongpeng (2017) assessed sustainable infrastructure in the success of a construction project, based on questionnaires that collected data on the importance of the criteria used to assess and develop a method of structured equations and factor analysis. Wallbaum et al. (2011) created a methodology to prioritize criteria of sustainability. Ozcan-Deniz and Zhu (2016) developed an approach to analyze changes in project conditions and their impacts on time, cost and environmental impacts, allowing the selection of more viable construction methods. Lin et al. (2016) proposed a quantitative method to evaluate the efficacy of a system of ideal ecological indicators. Lin et al. (2017) investigated the social questions of sustainability, offering a

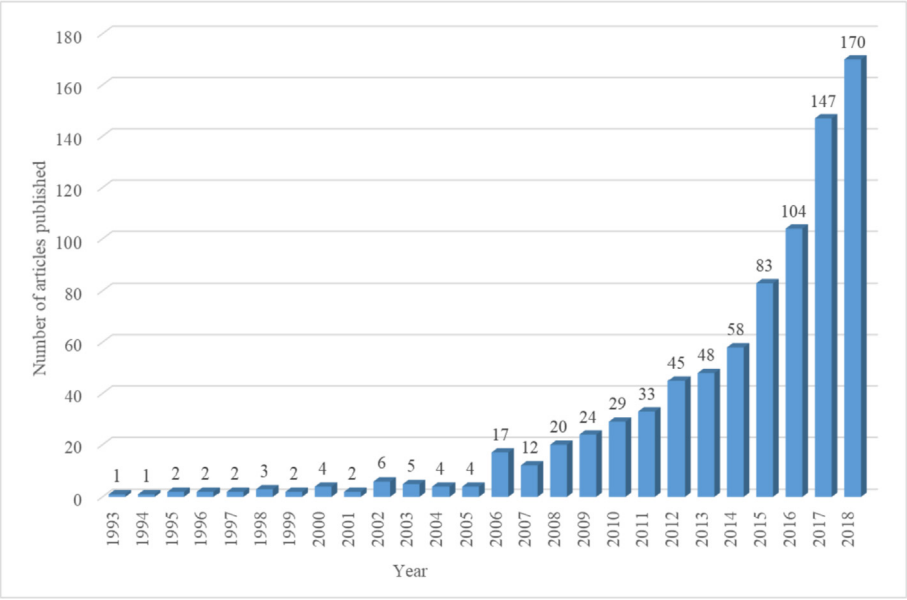

Fig. 3. Temporal distribution of articles.
Source: The authors.

comprehensive system of social responsibility indicators for megaprojects. Hosseini et al. (2018) and Akbari et al. (2018) conducted research to analyze the sustainability levels of megaprojects (large scale), using decision support systems.

Quantitative sustainability methodologies in the construction industry applied to the real estate sector that include multi- and single-family dwellings and commercial buildings were developed based on ISO 15392 (2008) or/and ISO 21929 (2011). These methodologies were used to identify environmental, social and economic aspects; create and/or adopt indicators for specific context, classify and assess construction projects. Among the methodologies developed are studies related to the selection of criteria and/or sustainability factors, applying multicriteria decision-making techniques in order to reduce uncertainties in the sustainability assessment process (Apanavičiene et al., 2015; Dobrovolskienė and Tamošiūnienė, 2016; Hassan, 2016; Namini et al., 2014b; Ruiz and Fernández, 2009); other authors created methodologies to construct an index to identify and measure sustainability and direct mitigating measures towards projects (Borja et al., 2018; Firmawan et al., 2016; Gultekin et al., 2013; Zhang et al., 2014). Medineckienė et al. (2010) analyzed the trend towards an impact of sustainable construction processes and materials in single-family dwellings. Salzer et al. (2016) examined the need for social housing in the Philippines built with alternative materials.

In order to broaden the search, some of the references from the articles included were investigated and described in this paragraph. Zobel and Burman (2004) conducted a significant study that helps researchers develop new methodologies. Based on the first environmental management guidelines (BS 7750; ISO 14.001 and 14.004), Johnston et al. (2000) devised a method to assess significant environmental aspects. Chen et al. (2004, 2000) used a qualitative approach to create a pollution index for the construction industry in order to provide quantitative measures on pollution, and later quantified the generation of material residue using a waste rate related to the cost of materials. Chen et al. (2005) used previous studies to select the best construction plan. Cheung et al. (2004) used the internet to establish an online system denominated WePass to assess environmental performance. Tam et al. (2004, 2006) suggested a specific tool for the construction industry able to environmentally evaluate construction activities, identify environmental performance indicators in construction management. Eom and Paek (2009) created an environmental risk index for outsourced contractors at building sites.

Gangolells et al. (2011, 2009) contributed with a predictive methodology to quantify the environmental impacts of construction processes/activities and extended their previous approaches by adding the concerns of parties interested in calculating the degree of the influence on assessment, as suggested by ISO 14.004 (2007). Fuertes et al. (2013) continued with Gangolells' research developing a causal model in an attempt to understand the environmental impacts. Gangolells et al. (2013) presented an innovative model to improve the integration of environmental management and health and safety systems in construction companies. Li et al. (2010) created a quantitative assessment of the environmental impacts of construction by applying Life Cycle Assessment methodology to construction processes, limiting analyses to equipment and materials. Jang et al. (2018) presented a sustainable development index to evaluate green technologies. Shen et al. (2005) developed a scoring method to measure the environmental performance of contractors and determine which factors affect environmental performance.

Fig. 4 presents a comparison between articles that use quantitative sustainability methodologies in the construction industry and the activities and/or products developed by engineering. The articles using quantitative assessment models identified in this review were divided into six types of construction activities and/or products and their amounts were normalized and presented in the polygon, where the vertices represent the activities and/or products and the radii the normalized number of articles. Most of the articles were in the area of multi-family dwellings (buildings), followed by urban infrastructure. Bentivegna et al. (2002) underscored that authorities developed a series of quantifiable criteria internationally. According to Fernández-Sánchez and Rodríguez-López (2010), linear infrastructure projects are not assessed by any tools. Finally, there are gaps in methodologies for single-family dwellings and mixed methodologies applied to dwellings and infrastructure.

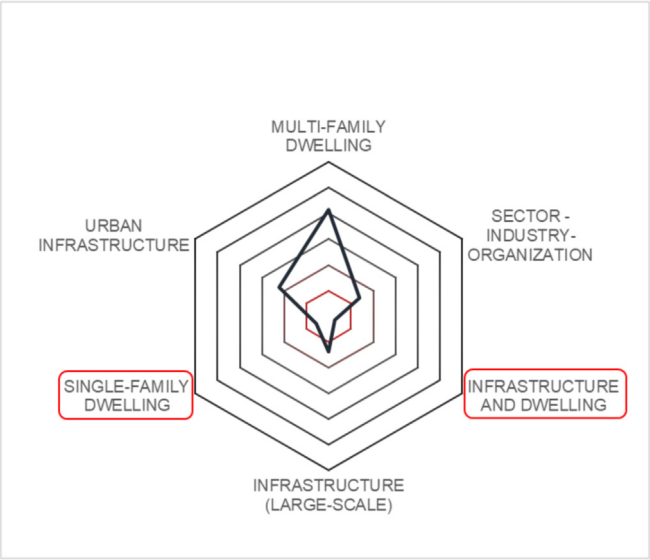

Fig. 4. Comparison of quantitative sustainability methodologies by type.
Source: The authors.

These findings indicate that single-family dwellings are less studied, possibly due to the absence of information, documentation and standardization, in addition to their inherent informality. The absence of data and lack of transparency in the information are challenges in identifying indicators of sustainability (Banihashemi et al., 2017). The authors of the review observed that the methodologies applied to dwellings and infrastructure were minimal. In practice, the difficulties in integrating the two series of data in order to build a methodology may result from the development of construction projects at different times and by different organizations.

3.2.2. Results of "environmental aspects" studies

A total of 365 articles were classified as "environmental aspects", and divided into 10 items. This distribution is presented in Table 1.

According to Zobel and Burman (2004), identifying environmental aspects in unregulated areas is more difficult and should be treated differently, and many authors prefer an approach aimed at identification processes in the construction industry. Fig. 5 shows the distribution of articles discussing the seven environmental aspects.

The review found that "waste" is the most widely studied environmental aspect, corroborating Teh et al. (2018), who emphasized that it represents a challenge to the construction industry, justifying studies showing that it contributes directly to 25% of the waste generated worldwide. Yahya and Halim Boussabaine (2006) found that waste production is associated with losses

Table 1
Distribution of articles by environmental aspects. Source: The authors.

ENVIRONMENTAL ASPECTS	NUMBER OF ARTICLES
emissions to air (atmosphere)	28
emissions to air (noise)	1
releases to water	49
releases to land	9
use of raw materials and natural resources	63
local/community environmental issues (incidents and accidents)	15
local/community environmental issues (transport)	60
local/community environmental issues (archeology)	1
local/community environmental issues (effects on biodiversity)	21
energy emitted (vibration)	0
waste	118

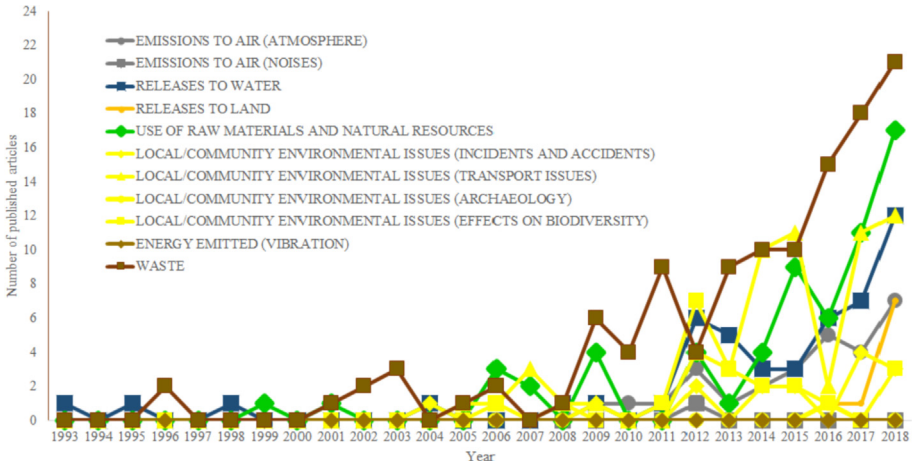

Fig. 5. Distribution of articles by aspects over time
Source: The authors.

(waste rate) of construction materials on site, having a direct economic impact on production costs. According to Kim et al. (2006), companies are obliged to establish waste management guidelines in compliance with existing laws.

"Local/community environmental issues accounted for 97 articles subdivided into the following topics: accidents and incidents; traffic; archeology and effects on biodiversity. According to Dobrovolskienė and Tamošiūnienė (2016), achieving sustainable development to meet the needs and objectives of all stakeholders will only occur when society is included in the research (Fig. 6).

"Use of raw materials and natural resources" ranked third in number of articles, exhibiting the same growth curve behavior as "waste' articles, which was expected given the correlation between the use of raw materials and waste generation. Ortiz et al. (2009)a,b underscored the increasing concern about resource depletion, due to the need to consume building materials.

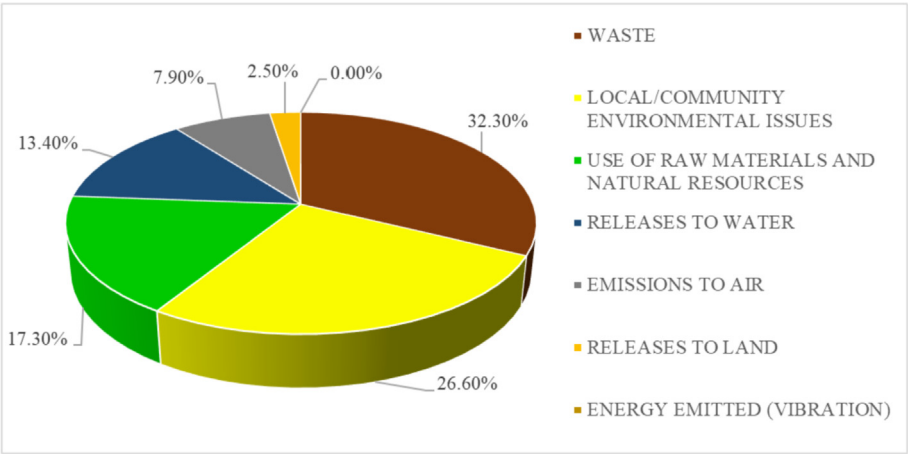

Fig. 6. Gravimetric composition of environmental aspects articles
Source: The authors.

The fourth environmental aspect, “releases to water", is related to the wasteful use of water at construction sites, in addition to surface and groundwater contamination. The number of articles on this topic highlights the need for studies on efficient water use and conservation at construction sites (Waidyasekara et al., 2017).

Scientific articles on “emissions to air (atmosphere and noise)” underscore concern about the need to reduce carbon dioxide emissions during construction and the air quality when using/operating the final product. Muleski et al. (2005) reported that construction activities are important sources of particulate emissions and few studies have been conducted at construction sites to garner more in-depth knowledge of this environmental aspect. Araújo et al. (2012) found that noise pollution studies are needed to measure and monitor its effects and dimensions in order to reduce the socioenvironmental impacts.

The sixth environmental aspect (“releases to land”) was discussed in only nine studies, demonstrating less concern about this issue. According to Qu and Long (2018), land use studies are needed in the future. Wu et al. (2018) contend that innovative and sustainable land use practices should be implemented and analyzed throughout the planning, construction, operation, maintenance and management processes.

No articles were found on the last environmental aspect, “energy emitted” (vibration), using our keywords, but the topic is reported in other research areas such as mechanical engineering and work safety.

The fact that environmental aspects have been poorly studied hinders sustainability management in the construction industry in terms of creating a standardized quantitative methodology that assesses issues related to identifying and evaluating indicators. Borja et al. (2018) proposed a quantitative methodology to predict environmental aspects, and conducted a case study to determine the construction activities with the greatest potential for environmental impact (resource consumption; pollutant emission; public services and transport). Fig. 6 shows the gravimetric composition of articles by environmental aspect and the result corroborates that reported by Borja et al. (2018). Yahya and Halim Boussabaine (2006) found that the construction industry uses an enormous amount of raw materials, with a significant environmental and financial impact. Minimizing material losses and the use of recycled materials are among the factors that reduce waste (Kim et al., 2006). These issues are reflected in research fields, causing the disproportionality illustrated in Fig. 6, which also depicts the correlation between aspects such as waste and the use of raw material/natural resources in the construction industry.

In addition, there is a group of articles denominated “others”, which was created in order to determine whether there are aspects related to sustainability management in the construction industry that have not been previously mapped. A total of 122 articles (14.73%) that were not assessed in the qualitative phase of this research were found. These articles discuss topics such as education, community environmental management, sustainable agriculture, sustainability in the automobile industry, and sustainable tourism, among others.

3.3. Results of the most widely cited analysis units detected by VOSviewer

VOSviewer identified the journals and institutions with the highest number of references in the 828 articles examined. This analysis will be presented separately for each of the types.

3.3.1. Results of the reference analysis unit; articles

A detailed analysis of the 18 most referenced articles detected by VOSviewer software was conducted. The topics discussed in the articles are divided into three groups: "sustainability in the construction industry”, waste related “environmental aspects”, and “others”. Fifteen studies on “sustainability in the construction industry” were divided into three specific topics: sustainable supply network, environmental assessment and environmental management.

Among the issues discussed are those related to sustainable management of the supply chain as a competitive strategy, including with analysis of the implications of logistics (Beske and Seuring, 2014; Carter and Rogers, 2008); life cycle assessment in the construction industry in order to determine environmental loads (Ortiz et al., 2009b); limitations in the current environmental assessment methods used for buildings (Ding, 2008); development of sustainable urbanization methods applied to urban infrastructures (Li et al., 2009); analysis of the barriers and drivers for sustainable buildings (Häkkinen and Belloni, 2011); application of decision support systems using multicriteria methods in environmental assessment methodologies (Taylan et al., 2014; Turskis et al., 2009); a method to establish sustainable performance criteria in selecting the construction plan in concrete buildings (Chen et al., 2010); proposal of a methodology to identify sustainability indicators in building projects (Fernández-Sánchez and Rodríguez-López, 2010); assessment of sustainable materials with the use of "green roofs” and their benefits in the operational phase (Getter and Rowe, 2006); exploratory studies of corporate sustainability reports (O’Dwyer et al., 2011); management practices to deliver sustainable projects (Robichaud and Anantatmula, 2011); challenges of project viability studies to comply with sustainable guidelines (Shen et al., 2010); determination of management knowledge and skills in green construction projects (Hwang and Ng, 2013).

With respect to environmental aspect studies, two authors published articles on "waste”, both aimed at reducing it; in the first, the authors analyzed waste quantification and sources in order to minimize the squandering of materials and in the second, they assessed the scant attention paid by architects to project design with a view to reducing waste (Bossink and Brouwers, 1996; Osmani et al., 2008).

In the “others” group, only 1 article discussed the main visual changes in forest landscape standards and processes in the Northeastern United States (Hessburg and Agee, 2003).

3.3.2. Results of the reference analysis unit: journals

A total of 299 journals were identified in the 828 articles analyzed by the software, 18 of which were the most widely referenced. Fig. 7 illustrates the network of links between journals, distributed into 4 clusters. The journal most referenced in the Web of Science database was the Journal of Cleaner Production, with 93 articles and 974 references. This is an international transdisciplinary journal aimed at research in clean, environmentally sustainable production practices, encompassing the environmental sustainability of companies, governments, teaching institutions, regions and societies (JCP, 2019). The second most cited is Building Research and Information, with 18 studies and 610 references.

The scope of this journal is buildings and their support systems. Its articles use evidence-based conceptual approaches that reflect the complexity and links between the cultural, environmental, economic, social, organizational, health, well-being, design and engineering quality of the building site (JBE, 2019). In third place is Resources Conservation and Recycling, with 29 articles and 563 citations. Its studies focus on sustainable management and resource conservation, emphasizing the transformation processes involved and the transition to more sustainable production and consumption systems (RCR, 2019). Sustainability lies at the center of Fig. 7, representing the yellow cluster, the 10th most referenced

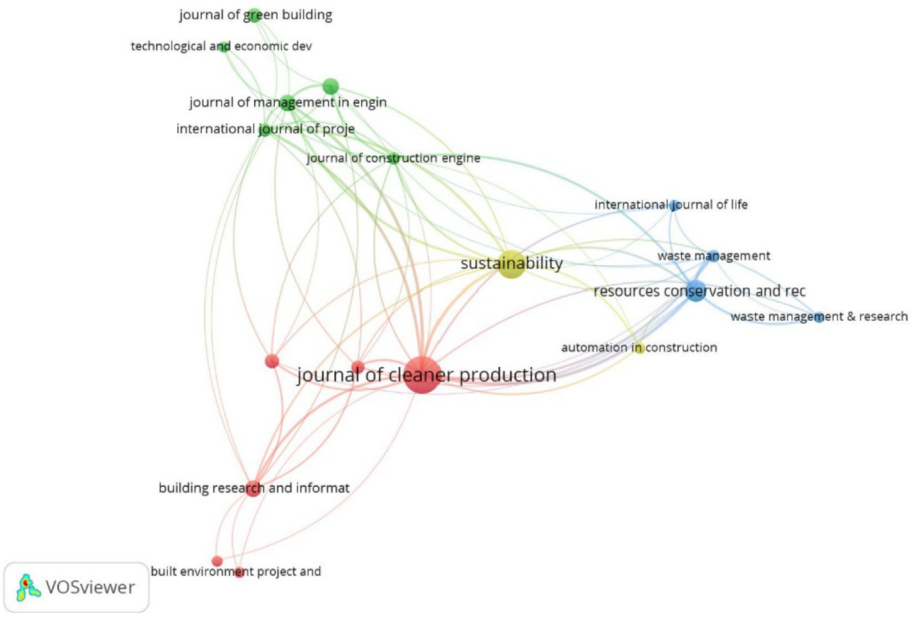

Fig. 7. Most referenced journal.
Source: The authors.

journal, with 185, but in third place in the number of links, and second in the number of published articles. It is an international interdisciplinary journal with studies related to sustainable development (S-OAJ, 2019).

3.3.3. *Results of the reference analysis unit: institutions*

A total of 951 institutions were found that conducted research in construction management and sustainability. Fig. 8 represents the network of links of the 18 most cited institutions. These facilities were distributed into five clusters; however, the fifth showed no links and is not represented in the figure.

Hong Kong Polytechnic University was the most referenced, with 628 citations in 33 published studies, obtaining 62 links with other institutions. It is considered one of the best universities in Asia, and its mission is to conduct high impact research that benefits the world, as well as stimulate critical thinkers, effective communicators, innovative problem solvers and socially responsible citizens (THKPU, 2019). The Chinese Academy of Sciences ranked second, with 270 references in 18 studies; however, it has only 3 links with other institutions, since it consists of a network of Chinese institutions that invests significantly in research (CAS, 2016). In addition to being a major economic power, the country

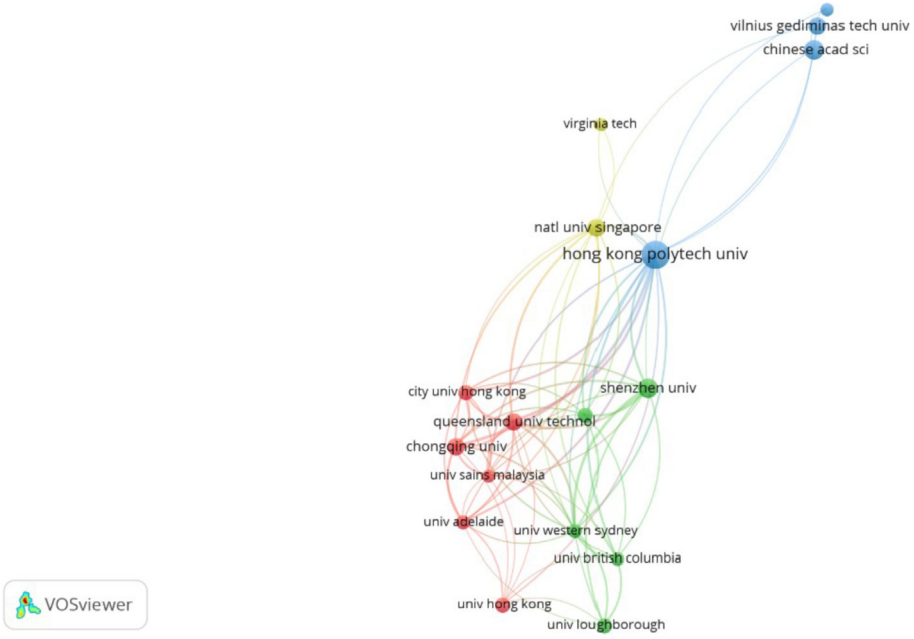

Fig. 8. Most cited institutions
Source: The authors.

boasts a number of universities focused on studies that cause relevant impacts in the area of construction management and sustainability. The third, Vilnius Gediminas Technical University, obtained 253 citations in 12 articles, and is considered one of the most important innovative institutions of higher learning in Lithuania, focusing on sustainable buildings, environmental and energy technologies, sustainable transport, mechatronics, information and communication technologies, research into materials and processes, engineering economics, management and communication (VGTU, 2019).

4. Discussion

Questions related to environmental assessments will always be imperfect (Johnston et al., 2000), since most sustainability assessment systems lack contextualization in their approach and methodological rigor (Namini et al., 2014a). Environmental impact assessments are inaccurate because they are often conducted using perception-based questionnaires (Akbari et al., 2018). Environmental aspects should be continuously updated; however, their identification is constantly associated with difficulties and confusion (Zobel and Burman, 2004). As such, identifying and classifying indicator systems is essential to assessing the efficacy of environmental aspects (Lin et al., 2017).

The assessment criteria of sustainable infrastructure may vary according to the type and location of the project (Lin et al., 2017). In addition, different project participants may have divergent opinions on assessment criteria (Fernández-Sánchez and Rodríguez-López, 2010). A working model should be created to assess the sustainability of infrastructure projects, adjusting to the assessment criteria with their respective weights and importance. However, data are required to help develop them, meaning new databases are needed to provide more evidence (Lützkendorf and Lorenz, 2005). Gangolells et al. (2009) suggested studies that implement methodologies in knowledge and information management systems based on the Web and databases.

Quantitative assessment methodologies that predict habitational sustainability should consider the results of local infrastructure evaluations. Since these assessments are integrated in practice (infrastructure and habitational), they should be evaluated separately. The habitational product of the construction industry is implemented only where there is infrastructure.

The low number of studies identified in this literature analysis demonstrated that some environmental aspects are not thoroughly investigated. The few published articles focus on soil contamination-modification; noise pollution, archeological impacts and vibrations, corresponding to 1.09%; 0.12%; 0.12% and 0.00% of the total analyzed. Environment-related disputes are increasing at building sites in South Korea, 86.6% of litigation cases were related to sound and vibration, 7.9% air pollution, 3.5% water pollution, 0.6% marine pollution and 1.3% other problems (Eom and Paek, 2009).

There are few studies on the construction industry aimed at developing quantitative methodologies in order to assess sustainability. Some environmental aspects are studied in depth while others are neglected. This clearly demonstrates that quantitative sustainability assessment methodologies, which are based on expert opinions on building, identifying and assessing sustainability indicators, may be significantly inaccurate. The scientific community investigating the construction industry needs to increase its knowledge of all the environmental impacts generated by their activities in order to create a solid scientific base to identify and assess the environmental aspects of projects.

A number of articles analyzed environmental aspects by applying Life Cycle Assessment based on ISO 14040/1998; 14042 and 14043/2000, showing the need for resources, emissions, energy and residue using inputs (raw materials and energy), system limits (life cycle) and outputs (emissions and releases).

Finally, except for China, there were few academic studies in developing countries, scarcely any assessments of single-family dwellings, a disproportionally small number of investigations on the types of environmental aspects, consisting primarily of those on “waste”, and a gap in research on “emitted energy” (vibrations).

5. Conclusions

This article is a systematic review of studies related to construction management sustainability. It presented the state of the art of the field and the gaps found in the literature regarding models to be developed in order to improve sustainability in construction and environmental aspects that have not been deeply studied. This analysis was conducted in three phases: (i) quantitative analysis, (ii) meta-analysis where the articles were filtered and clustered for bibliometric analysis, and (iii) a qualitative analysis. It was verified that few studies used quantitative methodologies (2.54%) to measure the environmental aspects generated by the activities and products of the construction industry and these were aimed more at multi-than single-family dwellings. In addition, quantitative assessment methodologies that predict habitational sustainability do not consider the results of local infrastructure evaluations, which may happen because of the lack of database and variation among the type of construction and location.

A total of 299 journals published articles on management – construction – sustainability, due to the multidisciplinary nature of the topic. Eighteen journals were the most influential, especially the Journal of Cleaner Production, with 93 articles and 974 references. The three main institutions in terms of the number of citations for their articles were Hong Kong Polytechnic University, Chinese Academy of Sciences and Vilnius Gediminas Technical University. This information illustrates the exchanges between Chinese researchers and China’s investment in academic research in recent years.

In the present study, we only analyzed articles indexed in the Web of Science database. The authors attempted to reduce losses by methodologically including some references of articles analyzed in the qualitative phase.

There is an imminent need for studies aimed at bridging existing gaps, including in developing nations, given the repressed demand for building construction in these countries that could have serious environmental impacts. These impacts are evident in the global need for conservation, since environmental impacts go beyond the geographical borders of the affected area, leading to global imbalance. Al last, it is important that in future research methodologies that consider a previous analysis of environmental aspects in the whole life cycle of buildings is developed.

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.

CRediT authorship contribution statement

Adolpho Guido Araújo: Conceptualization, Methodology, Software, Data curation, Writing - original draft. **Arnaldo Manoel Pereira Carneiro:** Supervision, Validation. **Rachel Perez Palha:** Conceptualization, Methodology, Supervision, Validation.

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