

Construction supply chain management: a scoping review

Gerenciamento da cadeia de suprimentos da construção: uma revisão de escopo

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Abstract

Studies related to construction supply chain management (CSCM) emerged in the mid-1990s to address the structural, economic and organizational nature typical of the construction industry. Previous researches sought to review the literature on CSCM, however, they usually focused on specific and well-defined issues. This article aimed to map the current areas and subareas of the CSCM. Adopting a bibliometric approach and following the PRISMA-ScR recommendations, a scoping review was carried out. With the help of the CiteSpace[®] tool, the information was viewed as a co-citation network, providing a panoramic view of how the main publications are distributed and networked, forming research areas and subareas. The key documents and the main authors were identified; the current situation and the emerging points of interest in the CSCM field were also revealed. This article establishes a knowledge base for future research, which can help scholars and managers to identify authors, documents and journals to be considered when dealing with certain topics of the CSCM.

Keywords: Construction supply chain management. Co-citation network. Bibliometric study. CiteSpace. PRISMA-ScR.

Resumo

Estudos relacionados à gestão da cadeia de suprimentos da construção (GCSC) despontaram em meados dos anos 90 para atender à natureza estrutural, econômica e organizacional típica da indústria da construção. Pesquisas anteriores buscaram revisar a literatura sobre GCSC, no entanto, geralmente concentradas em questões pontuais e bem definidas. Este artigo tem como objetivo mapear as atuais áreas e subáreas do GCSC. Adotando-se uma abordagem bibliométrica e seguindo-se as recomendações PRISMA-ScR uma revisão de escopo foi realizada. Com auxílio da ferramenta CiteSpace[®] as informações foram visualizadas em forma de rede de cocitações, proporcionando uma visão panorâmica de como as principais publicações estão distribuídas e interligadas em rede, formando áreas e subáreas de pesquisa. Os documentos chaves e os principais autores foram identificados; a situação atual e os pontos de interesse emergentes no campo do GCSC também foram revelados. Este artigo estabelece uma base de conhecimento para pesquisas futuras, podendo auxiliar estudiosos e gestores a identificarem autores, documentos e periódicos que precisam ser considerados ao lidarem com determinados tópicos do GCSC.

Palavras-chave: Gerenciamento da cadeia de suprimentos da construção. Rede de cocitações. Estudo bibliométrico. CiteSpace. PRISMA-ScR.

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Introduction

There are several studies on SCM from process-based manufacturing industries. Some of them even served as a basis for researchers dedicated to the construction industry. Akintoye (1995) and Agapiou *et al.* (1998), e.g., applied the Supply Chain Management (SCM) philosophy to construction supply chain (CSC) to set a relationship between local productivity and the improvement of materials. However, due to the transitory nature of construction projects, O'Brien (1999) pointed out that research related to manufacturing, while useful, does not apply easily to construction. Fernie and Tennant (2013) point out that the principles of supply chain management were neither generalized nor fully adopted in construction. In fact, CSC has its peculiarities: the existence of unique projects; composition by multiple self-protected and fragmented entrepreneurs; adverse and short-term transactional relationships; prevalence of competitive bidding; little information sharing; and little motivation for continuous learning (BEHERA; MOHANTY; PRAKASH, 2015). In addition, it works under cyclical demand (AKINTOYE; MCINTOSH; FITZGERALD, 2000) and the final product, supplied by order, receives strong influence from the customer (VRIJHOEF; KOSKELA, 2000).

Thus, studies related to construction supply chain management (CSCM) emerged in the mid-1990s to address the structural, economic and organizational nature typical of the construction industry. According to Xue *et al.* (2007), CSCM deals with the integration of the main members (customers/owner, designer, contractor, subcontractor and supplier) and construction business processes; emphasizes win-win, cooperative and lasting relationships; aims to improve construction performance and add value to the customer at a lower cost. Above all, the CSCM, like the SCM, brings an important change in the competitive model, considering that companies actually compete at the level of supply chains (VONDEREMBSE *et al.*, 2006).

The literature has strongly recommended CSCM as a good solution to reduce waste, costs and conflicts, improve value for customers and increase productivity and competitiveness in the construction industry (O'BRIEN; LONDON; VRIJHOEF, 2004; ALBALOUSHI; SKIMORE, 2008; BANKVALL *et al.* 2010; BEHERA; MOHANTY; PRAKASH, 2015; BATTULA; NAMBURU; KONE, 2020). Kim and Nguyen (2020) consider that chain management is the future of the construction industry. However, compared to other industries, CSCM is a relatively new topic that challenges new research to expand existing knowledge (TIWARI; SHEPHERD; PANDEY, 2014; AL-WERIKAT, 2017).

The research already carried out sought to review the literature on the CSCM, but generally focused on specific and well-defined issues that help in the development of other related study projects. Volk, Stelgel and Schultmann (2014) and Utama *et al.* (2016), e.g., reviewed construction studies on building information modeling (BIM) and international projects, respectively; these studies, therefore, can help other researchers interested specifically in the themes of BIM and international projects. Thus, in order to promote the development of CSCM and bring a vision of the existing whole, general, broader and more comprehensive issues, which may be applicable to different study projects, should be addressed.

This article aimed to map the current CSCM research areas and subareas, based on a bibliometric approach. We seek answers to the following questions:

- (a) (Q1) What are the main research areas/subareas?
- (b) (Q2) Where are the most active areas?
- (c) (Q3) What are the key documents?
- (d) (Q4) What is the origin and development of the research areas? and
- (e) (Q5) What are the promising study areas/subareas?

A bibliometric study was chosen because it introduces a systematic, transparent and reproducible process of identifying relevant works through objective and quantitative indicators (TRANFIELD; DENYER; SMART, 2003). The scoping review method was followed, which is also a systematic approach to synthesis of knowledge that allows mapping the literature (pointing out the general state of the research activity and clarifying areas of study) and identifying gaps with evidence where no research was conducted (ARKSEY; O'MALLEY, 2005; LEVAC; COLQUHOUN; O'BRIEN, 2010). The mapping of the literature as a scoping review is a preliminary study that allows the researcher to identify whether a complete systematic review is feasible (in terms of the number of existing researches), relevant (systematic reviews already carried out) and whether the effort to carry it out is justified (ARKSEY; O'MALLEY, 2005). Moreover, a scope study is

an appropriate alternative when the researched literature is vast and complex (GRIMSHAW, 2008; MOHER; STEWART; SHEKELLE, 2015), as is the case with CSCM.

This research mapped the relevant literature of the last 30 years and made it possible, with the help of a bibliometric tool capable of revealing patterns and new advances in CSCM research, to visualize information as a co-citation network. The study guides managers and researchers about the existing research on the CSCM, enabling the detection of individual and specific interests (including research gap), assisting in decision-making in relation to the theoretical-methodological field, identifying the feasibility, relevance and the effort to carry out a complete systematic review, in short, facilitating the immersion of the scholar in a certain area or subarea of research.

Method

This study followed the scoping review method. The guidelines of Tricco *et al.* (2018) that propose Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) and their extensions for Scope Reviews (PRISMA-ScR) were adopted. In the following subsections, the items related to the method and activities carried out in this research were detailed.

Research protocol

As an initial step to guide the research, a protocol was developed that included the research objectives and questions, the selected initial studies and the source selection criteria. It also included the search and selection strategies for primary studies, as well as guidelines for the processes of extracting information and summarizing results. The protocol was registered at Open Science Framework (OSF) on May 12, 2020 (access link: <http://osf.io/zm4qh>).

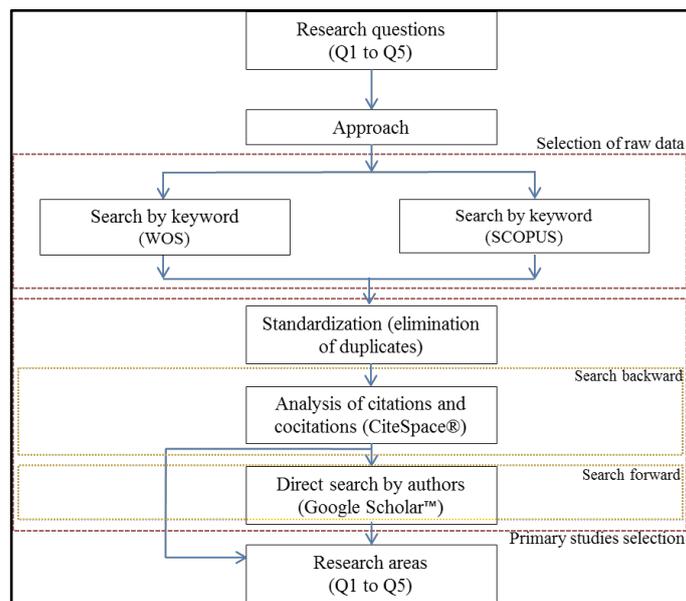
Eligibility criteria

To be included in the review, the documents had to be related to construction supply chain management. To ensure the scope of the research and avoid omission of the target literature, “article”, “proceedings paper” or “conference paper” and “review” or “conference review” were included, without language limitation, published in the period from 1990 to 2020.

Research strategy and information sources

The sequence of activities followed to carry out this research is described in Figure 1. After the research questions were defined, a bibliometric approach was chosen to conduct the present study.

Figure 1 - Research strategy



Data were selected in two stages:

- (a) selection of raw data (search by keywords); and
- (b) selection of primary studies (backward and forward search).

The congruence of the data obtained in the search backward and forward resulted in the areas related to CSCM.

In the first data selection (raw data selection), a search by keywords was carried out in the categories:

- (a) title;
- (b) abstract; and
- (c) keyword.

The bases used to survey the raw data were the Web of Science (WoS) – Main Collection (Clarivate Analytics) and Scopus (Elsevier).

Each database was searched through its proprietary search engine interface, using the following search string: ["supply chain management" and ("construction industry" or "building" or "AEC")] or ["construction supply chain"]. The retrieval was carried out on May 13, 2020. Subsequently, the results were exported from WoS (in *.txt format) and Scopus (in *.RIS).

Selection of primary studies

In this stage (selection of primary studies), a backward search was carried out (review of references of the selected works) and forward search (review of what was published after an original work), as proposed by Webster and Watson (2002).

Data imported from WoS and Scopus were standardized (elimination of duplicates) and processed with the aid of CiteSpace[®] v.6.7.R1 (open source bibliometric software, free and easy to handle). Through co-citation analysis, the software maps and explores trends in the literature, including identifying critical moments in the development of a field or domain (CHEN, 2006, 2013, 2016).

For the backward search, a co-citation analysis was used by counting the frequency of the pairs of documents simultaneously cited in a third work. The more often two papers are cited concurrently, the greater the likelihood of presenting associated content (SPINAK, 1996) and representing the knowledge structure of an area perceived by the researchers (GMÜR, 2003). Thus, there is similarity in content when two or more works are cited together in a third survey and the higher the frequency of co-citation, the closer the relationship between them and the greater the recognition by the researchers.

CiteSpace[®] designed the co-citation networks that were formed, showing the salient traces of the related research activities. Each point represents a node (reference). Nodes are connected by co-citation links (lines that connect the nodes). The most prominent references (nodes) that appeared were those that were highly cited, so they refer to relevant/seminal works in the study area. The title, summary and keywords of the publications of the main clusters that were formed were examined. When it was not possible to extract the necessary information, the analysis was extended to the full text. The starting parameters were as follows:

- (a) Time Slicing: 1990–2020;
- (b) years per slice: "1";
- (c) source of term: title, abstract, author's keywords and keyword Plus;
- (d) type of node: references; and
- (e) selection criteria: the top 50 (most cited).

To identify and analyze the research areas, the following CiteSpace[®] functions were used: clustering or grouping (approximation of objects with similar characteristics), labeling (context indication), burstness (detection of increase in citation) and "TimeLine" (reflects boundaries and trends). The citation burst relates a specific publication to an increase in citations, capturing an active area of research, or an emerging trend (CHEN, 2006). "Frequency" (counts the frequency of document citation), "Centrality" (translates the importance of intermediating nodes in the network), "burst" (identifies emerging interests), "modularity" (points out the clarity of the network structure), "Silhouette" (measures the homogeneity of the cluster members) and were some metrics used here to present the structure and distribution of scientific knowledge.

In CiteSpace[®], betweenness *centrality scores* are normalized to the range of [0, 1]. A high centrality node (reference) establishes links with other documents. This index was used to discover and measure the importance of the literature.

Direct search by authors was the technique used for the forward search. It basically consisted of tracking the later works of the authors who had their works (related to CSCM) highlighted in the search backward, identifying whether they remained in the same research area, left for some derivation or even produced nothing more about the subject matter of study. For that, the titles that returned in the “advanced search” of the Google Scholar[™] (GS) search engine were analyzed. Abstracts and full texts were accessed when necessary to extract complete information. We opted for GS because of its scope. There is strong evidence that it finds significantly more publications than Wos and Scopus in all study areas (HARZING, 2014; PRINS *et al.*, 2016; MARTÍN-MARTÍN *et al.*, 2018).

Data charting

A data graph form was discussed and developed (Figure 2) to determine which variables to extract after the second screening. Each extraction field has a data item, a value (numeric or semantic) that translates the investigated variable, and one or more sources that reveal the origin of the data (from where or how it was obtained).

As a pre-existing categorization was not identified in the literature, a specific and independent extraction of topics was chosen, as suggested by Petersen, Vakkalanka and Kuzniarz (2015). The authors analyzed the documents (title, keywords, abstract and, if necessary, the full text) to extract the main content (topic) of each study. To reduce bias, following the recommendation of Petticrew and Roberts (2008), all extractions were reviewed and reassessed by another reviewer (co-authors).

The topics were also used as a basis for building a subclassing scheme within the identified research areas. In this scheme, through an iterative process that involved, when necessary, merging and renaming topics, the documents were grouped into subcategories (specializations and derivations within the research areas).

Figure 2 - Data extraction form

| DATA ITEM | VALUE | SOURCE |
|---------------------|---|--------------------------------------|
| Author | Surname of the first author | Citespace [®] |
| Year of publication | Calendar year of publication | Citespace [®] |
| Source | Journal or Publisher's name | Citespace [®] |
| Cluster ID | Cluster identification member | Citespace [®] |
| Document title | Document's name | Web search engines |
| DOI | Numbers and letters to identify documents on digital networks | Citespace [®] and searchers |
| Sector | Specific study of construction or other industries | Document |
| Topic | Summary of the main content of the document | Document |

Synthesis of results

The information for each extracted item was tabulated. The analysis of the general results took place after the second screening. An overview of the CSCM research areas and subareas was presented. Co-citation networks, timelines and concept maps illustrate the findings. Concept maps were created with the help of the online tool GoConqr (<https://www.goconqr.com>). The individual characteristics of the key documents and the Top references were presented in a table. Finally, the findings of the scoping review were summarized and discussed.

Results and discussions

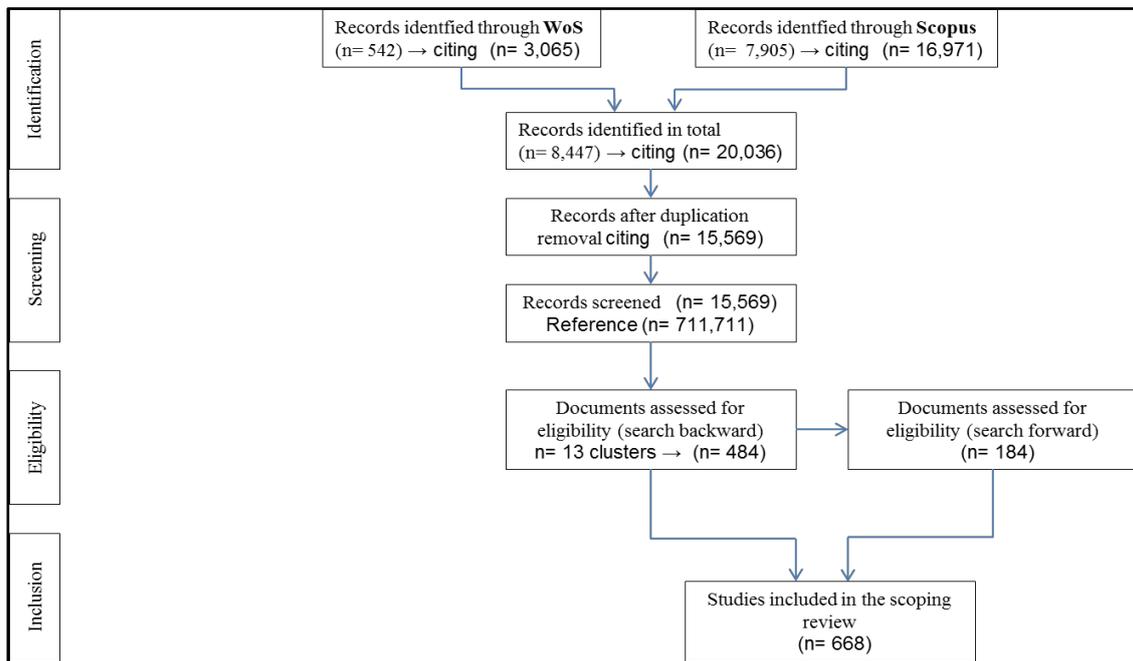
Selection of sources

At first, a total of 8,447 documents were retrieved (542 from WoS and 7,905 from Scopus). These documents were cited by 20,036 other works (3,065 from WoS and 16,971 from Scopus). After the first screening (elimination of duplicates), 4,467 documents were excluded, leaving a total of 15,569 documents, which resulted in 711,711 references. With the help of CiteSpace[®] (second screening), we have grouped the 711,711 references from 15,569 documents into 13 main clusters containing 484 members (works). In this 484 works, 187 authors were identified, who published 1,872 works related to CSCM. Thus, 2,356 works were included in the scoping review: 484 composed the search backward and 1,872 gave rise the search forward. The source selection process is shown in Figure 3.

Co-citation analysis

The analysis of document co-citations was used to reveal the underlying structure (research areas) around the construction supply chain management and to show the number and authority of citations.

Figure 3 - Source selection process



Document co-citation network

The document co-citation network is shown in Figure 4. It contains 876 nodes and 3,475 links (lines that represent the document co-citation relationship). Each node represents a document (reference) and is marked with the name of the first author and the year of publication. The thickness of the nodes (some of them marked by concentric rings) shows the frequency of co-citation of the documents. The colors of the nodes and links (e.g., gray, blue, green, yellow, orange and red) correspond to different years from 1999 to 2020 of first occurrence. The references with high centrality and burst are highlighted by purple and red rings, respectively. The thicker the highlight, the stronger the burst and/or the centrality. In the presented network, the dominant color is gray, corresponding to occurrences from 1999 to 2010. Eastmann *et al.* (2011), Ghisellini, Cialani and Ulgiati (2016) and Kirchher, Reike and Hekkert (2017) correspond to the largest nodes in the network; they consequently had the highest citation frequencies (196, 174 and 118, respectively). Eastmann *et al.* (2011) also had the highest burst strength (28.50). Briscoe and and Dainty (2005) emerged among the major centralities (0.20).

Clustering

Subsequently, the CiteSpace[®] clustering function was used to identify groups, or rather, research areas of greater prominence. The clusters were preferably labeled using the keywords of the references, which function as the core and essence of the publications (HE; WANG, 2015). The reference titles were the second option. The internal components (subclassification) of each cluster (area) were also consulted (see Figure 5). The labels of the clusters, therefore, point to the context (research area) in which they are most cited. The log-likelihood ratio (LLR) algorithm was used to select, among the three highest scores that retrieved, the most appropriate label for the cluster, following exclusivity and coverage criteria, as recommended by Chen (2016). Clusters #1, #4, #7, #9, #18 and #19 received alternative labels (not corresponding to the automatic labeling option: Keyword, first line). A total of 174 clusters were identified, with 13 main (significant) co-citation clusters, as shown in Figure 5.

Figure 4 - Document co-citation network

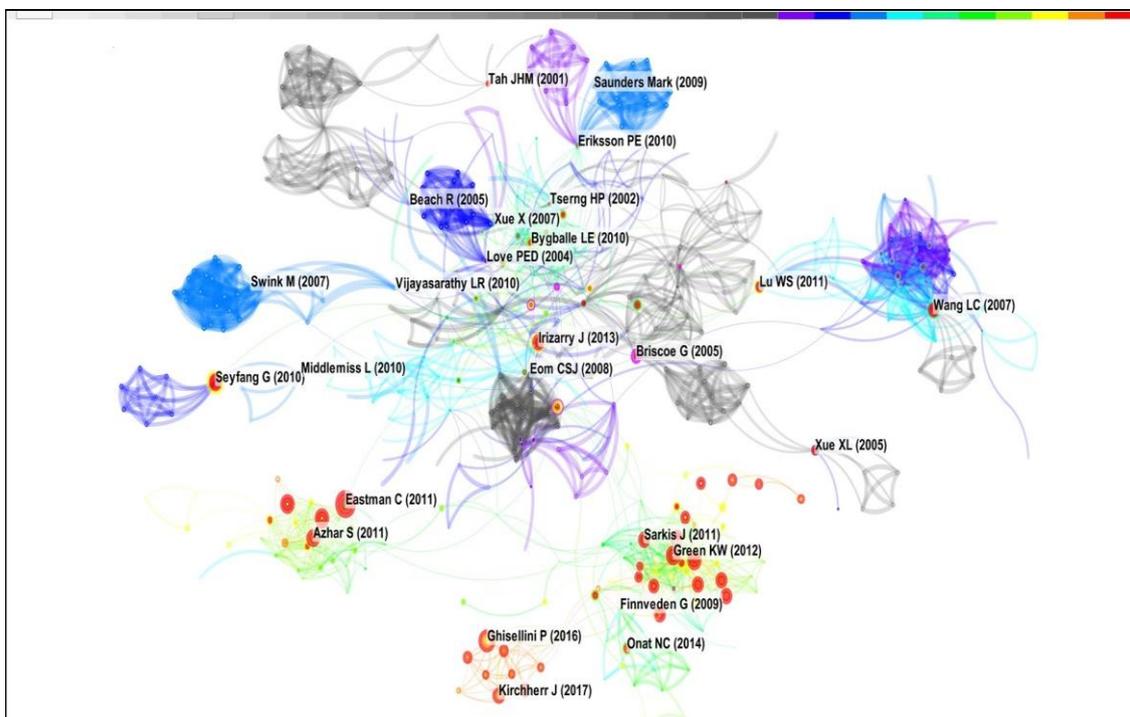
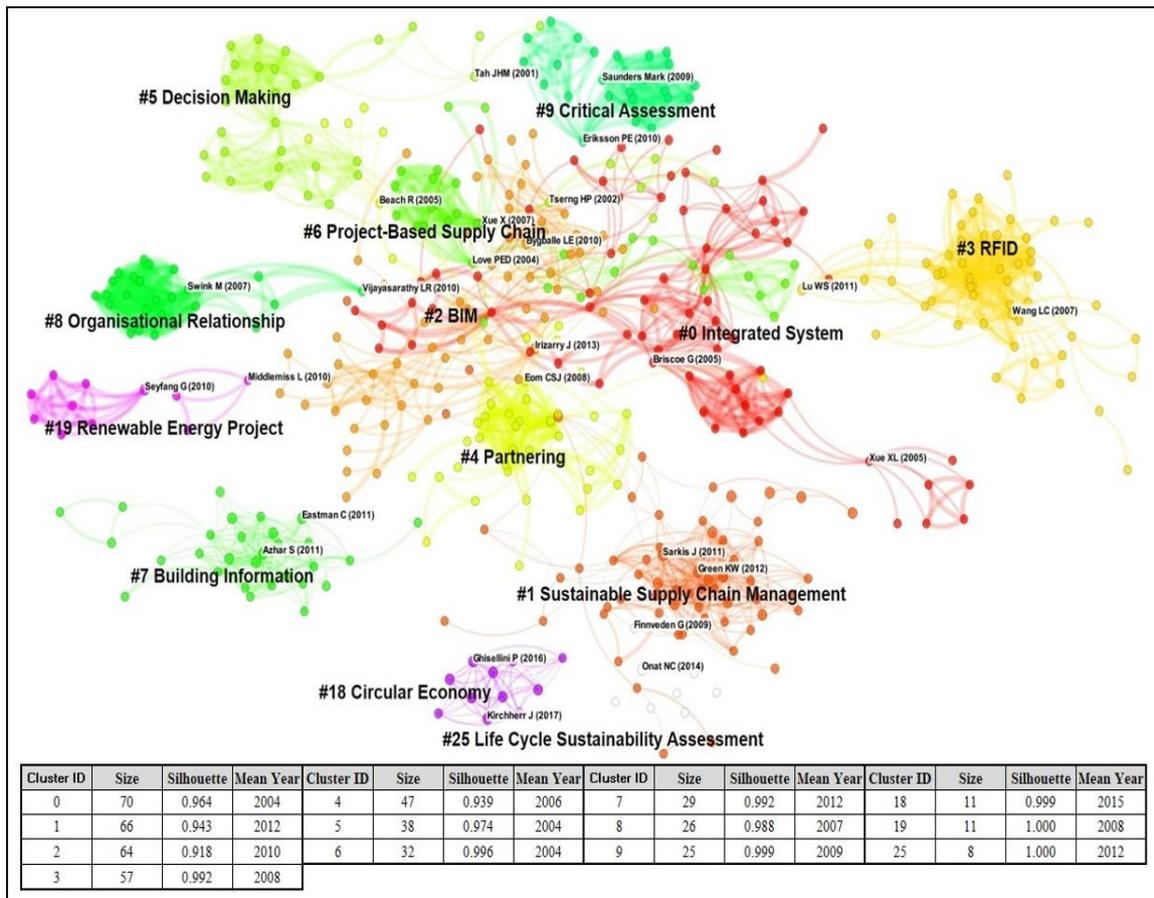


Figure 5 - Document co-citation network - clusters and descriptors



The cluster modularity Q at 0.9208 (close to 1.0) indicates that the network formed is partitioned into loosely coupled clusters (the different clusters are loosely coupled), or, in other words, the areas of the CSCM domain are clearly defined in terms of co-citation clusters. The 0.3316 silhouette suggests that the homogeneity (cohesion) of the 174 clusters, on average, is not very high. This is mainly due to the presence of several small clusters. However, the largest and most frequently cited clusters, main clusters (#0 to #9, #18, #19 and #25), the focus of our review, have sufficiently high silhouette values (with silhouette scores from 0.918 to 1). The descriptors (size, silhouette, average year and label) of the main clusters are listed in Figure 5. The size refers to the number of publications (members) within the cluster. There are 70 members in cluster #0, which is the largest. The number in cluster #25 was the lowest, with only eight members. The average year indicates whether the cluster is made up of newer or older documents. Thus, clusters #0, #5 and #6 dating from 2004 contain older publications, while cluster #18, from 2015, is composed predominantly of more recent documents. The oldest document is that of Hafeez *et al.* (1996), which is part of cluster #39. These authors described the analysis and modeling of dynamic integration of a steel industry supply chain that served the construction industry.

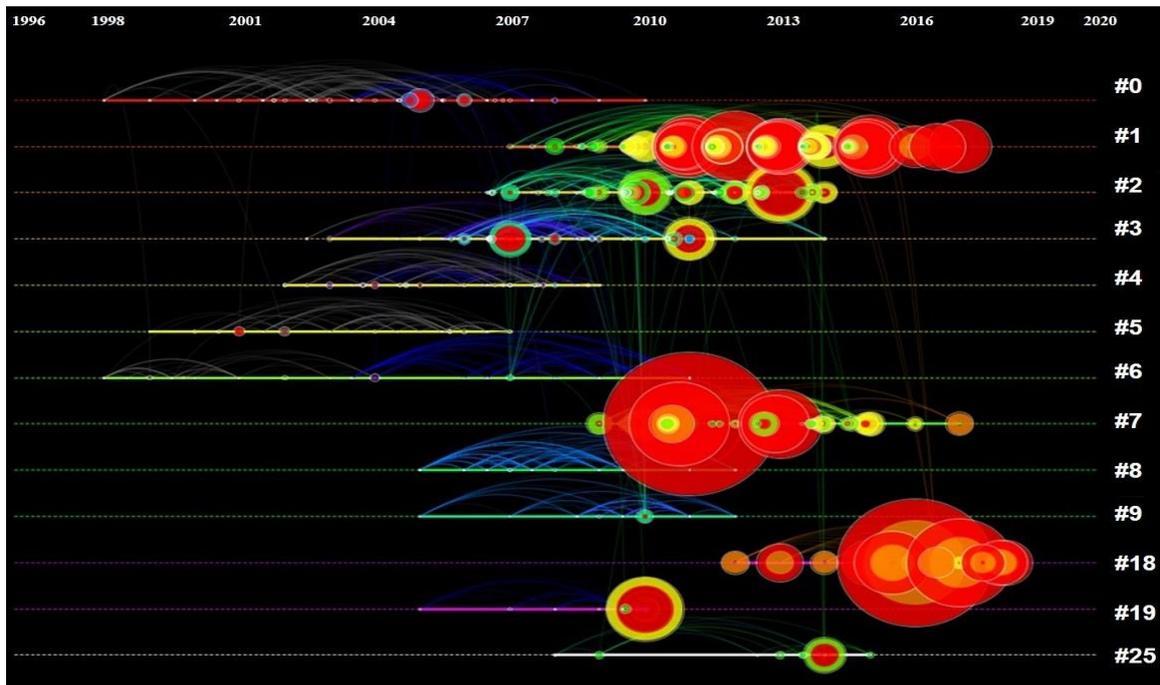
Origin and historical development of research areas

To understand the origin, development and current status of the clusters (research areas), a visual analysis of the network’s timeline (Figure 6) was made.

In the timeline view (Figure 6), it is observed that the research areas with more recent studies (close to 2019) are:

- (a) *circular economy* (cluster #18);
- (b) *sustainable supply chain management* (#1); and
- (c) *building information* (#7).

Figure 6 - Timeline view of the main clusters



Areas such as *decision making* and *partnering*, e.g., have not had a volume of publications for a long time (since ≈ 2007 and ≈ 2009 , respectively), which shows a discontinuity of connections.

Research areas and sub-areas

From the iterative analysis of the 484 publications that make up the 13 main clusters, a subclassification scheme (with percentage of occurrence) of the research areas emerged (see concept map in Figure 7). It started from a central topic (Construction Supply Chain Management) and branched it into subtopics (research subareas). So, e.g., in the area of renewable energy project (cluster #18) there are studies on renewable energies (50%), low carbon communities (20%), sustainable construction (20%) and climate change (10%). The largest volume of studies (15.57%) concerns subtopics (benefits, implementation, interoperability, GIS, RFID, e-business, lean construction, precast, sustainability, supplier management and economic impact) related to BIM (clusters #2, #3 and #7). Subtopics related to partnership (barriers, practices, trust, critical success factors, performance indicators, procurement, public-private partnership and alliance) and integration (from SCM and suppliers) emerge in the sequence with 10.60% and 8.17 % works, respectively. Economic issues, despite few studies (2.43%) in general, are studied in several areas (Clusters #0, #2, #5, #6, #7, #9 and #25). Finally, the analysis identified a preference for three major themes:

- information technology (26.27%), distributed in clusters #0, #2; #3, #4; #5, #7 and #8;
- relationship (25.65%), found in clusters #0, #1 and #2 to #9; and
- sustainability (12.36%), in clusters #0, #1, #2, #7, #8, #18, #19 and #25.

Key documents

Key documents (relevant to the study in the area) of each cluster refer to the 3 main documents with the highest frequency of co-citation. These documents, in fact, significantly influence the definition of the label of each cluster, which deserves attention. The citation burst and centrality scores also reveal the relevance of each document. Table 1 lists the key documents for each cluster (area) that includes the 3 most cited documents (see column "Freq"), the documents with the highest burst strength (in red) and those with the highest centrality (in green) in each research area. The source of the publications ("Source") and the topic ("Topic") are also informed.

Table 1 - Key documents of the 13 main research areas (To be continued...)

| Cluster ID | Key Documents | Source | Freq | Burst | Cent | Topic (Supply Chain) |
|------------|---------------------------------------|----------------------|------|-------|------|--|
| 0 | Xue <i>et al.</i> (2005) | AUTOMAT CONSTR | 41 | 20.16 | 0.02 | An Agent-based framework for CSC coordination |
| | Briscoe and Dainty (2005) | SUPPLY CHAIN MANAG | 23 | 11.50 | 0.20 | Key principles to be followed to achieve CSC integration |
| | Voordijk, Meijboom and De Haan (2006) | INT J OPER PROD MAN | 21 | 10.03 | 0.01 | Modularity in the CSC |
| 1 | Green <i>et al.</i> (2012) | SUPPLY CHAIN MANAG | 98 | 15.84 | 0.01 | Green supply chain management practices: impact on performance |
| | Sarkis, Zhu and Lai (2011) | INT J PROD ECON | 85 | 20.10 | 0.02 | Green supply chain management review |
| | Henseler, Ringle and Sarstedt (2015) | J ACAD MARK SCIEN | 83 | | 0.00 | Structural equation modelling based on variance |
| | Hair, Ringle and Sarstedt (2011) | PLS-SEM | 75 | 23.90 | 0.00 | Modelling partial least squares structural equations |
| | Meng (2012) | INT J PROJ MANAG | 47 | 18.61 | 0.12 | Project performance and relationship management |
| 2 | Irizarry, Karan and Jalaei (2013) | AUTOMAT CONSTR | 83 | 24.65 | 0.05 | CSC monitoring through the integration of BIM and GIS |
| | Bygballe, Jahre and Swärd (2010) | J PURCH SUPPLY MANAG | 65 | 27.13 | 0.01 | Partnership in CSC: a review |
| | Cheng <i>et al.</i> (2010) | AUTOMAT CONSTR | 39 | 15.36 | 0.00 | A service oriented framework for CSC integration |
| | Akintoye and Main (2007) | ENG CONSTR ARCHIT MA | 7 | 3.53 | 0.25 | Collaborative relationships in construction (critical success factors) |
| 3 | Lu, Huang and Li (2011) | AUTOMAT CONSTR | 64 | 14.20 | 0.09 | Applying RFID in construction project management |
| | Wang, Lin and Lin (2007) | ADV ENG INFORM | 54 | 22.20 | 0.02 | A RFID-based CSC management application |
| | Shin <i>et al.</i> (2011) | AUTOMAT CONSTR | 21 | 11.39 | 0.00 | RFC-based CSC management based on RFC |
| 4 | Chan <i>et al.</i> (2004) | J CONSTR ENG M | 10 | 5.88 | 0.02 | Critical success factors for partnership projects |
| | Beach, Webster and Campbell (2005) | INT J PROJ MANAG | 10 | 5.35 | 0.01 | Partnerships: progress in the construction industry and implications for suppliers |
| | Eom, Yun and Paek (2008) | J CONSTR ENG M | 10 | 4.87 | 0.08 | Partnership: assessment and management of subcontractors |
| 5 | Tah and Carr (2001) | ADV ENG SOFTW | 19 | 12.30 | 0.04 | Framework for project risk knowledge management in the CSC |
| | Tserng and Lin (2002) | AUTOMAT CONSTR | 17 | 11.16 | 0.04 | Subcontracting model and accelerated acquisition for construction projects |
| | Mitkus and Trinkūniene (2006) | J CIV ENG MANG | 5 | | 0.01 | Decision support system |

Table 1 - Key documents of the 13 main research areas (continuation)

| Cluster ID | Key Documents | Source | Freq | Burst | Cent | Topic (Supply Chain) |
|------------|--|------------------------------|------|-------|------|--|
| 6 | Love, Irani and Edwards (2004a) | SUPPLY CHAIN MANAG | 17 | 9.23 | 0.04 | Integration of design and project production processes |
| | Xue <i>et al.</i> (2007) | INT J PROJ MANAG | 12 | 5.51 | 0.04 | Coordination mechanisms in the internet environment |
| | Wong (1999) | TOTAL QUAL MANAGE | 10 | 6.74 | 0.00 | CSCM issues in total quality |
| 7 | Eastman <i>et al.</i> (2011) | John Wiley & Sons, Inc (Ed.) | 196 | 28.50 | 0.05 | BIM handbook: a guide |
| | Azhar (2011) | LEADERSHIP MANAG ENG | 114 | 25.83 | 0.00 | BIM: trends, benefits, risks, and challenges |
| | Bryde, Broquetas and Volm (2013) | INT J PROJ MANAG | 95 | 21.46 | 0.00 | BIM: project benefits |
| 8 | Vijayarathy (2010) | INT J PROD ECON | 4 | | 0.01 | Multidimensionality of supply integration and its relational background |
| | Koufteros, Edwin Cheng and Lai (2007) | J OPER MANAG | 3 | | 0.00 | Supplier integration (Theory of social networks) |
| | Sezen (2008) | SUPPLY CHAIN MANAG | 3 | | 0.05 | Effects of design, integration and information sharing on supply chain performance |
| 9 | Eriksson (2010) | SUPPLY CHAIN MANAG | 23 | 10.58 | 0.06 | Lean construction (collaboration and performance) |
| | Saunders, Lewis and Thornhill (2009) | Pearson Education | 3 | | 0.00 | Research methods for business students |
| | Black (2010) | John Wiley & Sons, Inc (Ed.) | 2 | | 0.00 | Business statistics: for contemporary decision making |
| 18 | Ghisellini, Cialani and Ulgiati (2016) | J CLEANER PROD | 174 | | 0.00 | Circular economy (characteristics and perspectives) |
| | Kirchherr, Reike and Hekkert (2017) | RESOUR CONSERV RECYC | 118 | | 0.00 | Circular economy (conceptualization) |
| | Lieder and Rashid (2016) | J CLEANER PROD | 86 | | 0.00 | Implementation of the circular economy in manufacturing systems |
| | Genovese <i>et al.</i> (2017) | OMEGA | 41 | | 0.03 | Sustainable supply chain management and circular economy |
| 19 | Seyfang (2010) | ENERG POLICY | 92 | 20.33 | 0.02 | Sustainable housing (carbon reduction) |
| | Middlemiss and Parrish (2010) | ENERG POLICY | 11 | 6.65 | 0.01 | Grassroots initiatives and creation of low carbon communities |
| | Walker <i>et al.</i> (2007) | GLOBAL ENVIRON POLIT | 5 | | 0.00 | Renewable energies in the United Kingdom (local community) |
| 25 | Onat, Kucukvar and Tatari (2014) | BUILD ENVIRON | 50 | 21.89 | 0.03 | The carbon footprint of US buildings (life cycle assessment) |
| | Finnveden <i>et al.</i> (2009) | J ENVIRON MANAGE | 10 | 5.27 | 0.04 | Review of recent life cycle assessment methods |
| | Kucukvar and Tatari (2013) | INT J LIFE CYCLE ASS | 9 | | 0.00 | Sustainability assessment for the US construction industry |

The research papers included in this stage (Table 1) were published in journals (93.02%) or in books. Journal articles have been published in 24 different Journals, with only 8 of them specialized in the Architecture, Engineering and Construction (AEC) industry: Building and Environment, Automation in Construction, Engineering, Construction and Architectural Management, Journal of Civil Engineering and Management, and Journal of Construction Engineering and Management. Automation in Construction, a journal focusing on construction technologies, was the source that published the largest number of documents (6 – clusters #0, #2, #3 and #5) of those listed in Table 1, followed by two journals specially dedicated to the publication of studies on management: Supply Chain Management (5 – clusters #0, #1, #6; #8 and #9) and International Journal of Project Management (4 – clusters #1, #4; #6 and #7). Book documents (3) were published by two different publishers: John Wiley & Sons, Inc (2) and Pearson Education (1).

The “Topic” column in Table 1 summarizes the main content of each publication. It should be noted that publications highlighted in blue do not refer exclusively to the CSC. This is because the references of the selected works were processed, that is, the documents referenced by authors (researchers) from AEC were considered in this research. So, e.g., in cluster #1, sustainable supply chain management, the main representative documents were Green *et al.* (2012), Sarkis, Zhu e Lai (2011), Henseler, Ringle and Sarstedt (2015), Hair, Ringle and Sarstedt (2011), and Meng (2012). Only Meng (2012) refers exclusively to the construction supply chain. The first three works were the most cited in cluster #1; Hair, Ringle and Sarstedt (2011) had the highest centrality (0.12) and Meng (2012) had the strongest citation burst (23.90). Green *et al.* (2012) investigated the impact of green supply chain management (GSCM) practices on performance. Sarkis, Zhu and Lai (2011) developed an organizational theoretical review on GSCM. Henseler, Ringle and Sarstedt (2015) talked about modeling structural equations based on variance.

As noted in clusters #0, #4, #5, #6, #7, #9, #19 and #25, the most cited document in each cluster was also, cumulatively, the strongest citation burst (see Table 1). Seyfang (2010), e.g., which dealt with sustainable housing (carbon reduction), aroused emerging interest (citation burst = 20.33) and also had the highest frequency of citations (relevance to the scientific community) in the area of renewable energy project (cluster #19). On the other hand, Ghisellini, Cialani and Ulgiati (2016) and Vijayasathy (2010), respectively in clusters #18 (circular economy) and #8 (organizational relationship), had the highest frequency of citations (174 and 4), but did not even score any citation burst strength.

The centrality values identified in the present study (Table 1) are low (with scores from 0.01 to 0.25), indicating that, in general, there is low betweenness strength between the documents and reduced influence between the groups. In fact, many documents returned 0.00 centrality, such as Azhar (2011), Saunders, Lewins and Thornhill (2009) and Kucukvar and Tatari (2013). In most cases (clusters #0, #1, #2, #4, #8, #18 and #25), even the highest centrality document did not match the one that received the most citations. Akintoye and Main (2007), e.g., had the highest centrality score (0.25) in cluster #2 (and also in relation to the other clusters), but had a low citation frequency (7).

Most active areas

To detect the most active research areas, the CiteSpace[®] citation burst function was used, which is based on the Kleinberg (2003) algorithm. The citation burst encompasses two measures: the strength of the burst and the time (period) of the burst. The strength refers to the sudden increase in the frequency of reference citation and the time refers to the period of duration of this burst (which can extend for one or several years). Thus, we evaluated whether a specific publication (reference) was strongly cited (aroused the interest of the scientific community) at a certain moment (over a period of time). The characteristics of temporal distribution and strength variability (citation burst detection) may reflect the research fronts and the development trend in the domain of knowledge.

Table 2 shows the 25 references with, simultaneously, stronger citation bursts, of longer duration and that started first, in the period from 1999 to 2020. References with high values in the column “Burst strength” can be considered relevant in the field of CSCM. The “Topic” column summarizes the main content of each publication, “Begin”, “End” refers to the duration of the citation burst and “ID” is the cluster number. Our analysis found that the paper by Wang *et al.* (2007), which deals with “RFID-based supply chain management application.”, has the longest lasting and strongest citation burst (22.1952). This burst lasted 7 years, from 2008 to 2015, but it does not correspond to the longest time interval. The paper that remained for the longest time (8 years – from 2005 to 2013) was Xue *et al.* (2005), which deals with “The Agent-based framework for supply chain coordination”, but corresponds to the second strongest citation burst (20.1625).

Table 2 - Top 25 references with the strongest citation bursts in the period from 1999 to 2020

| References | Topic | Strength | Begin | End | 1998 – 2020 | # |
|---------------------------------------|--|----------|-------|------|-------------|---------|
| Wang, Lin and Lin (2007) | A RFID-based supply chain management application. | 22.1952 | 2008 | 2015 | | 3 |
| Xue <i>et al.</i> (2005) | An Agent-based framework for supply chain coordination. | 20.1625 | 2005 | 2013 | | 0 |
| Feng and Wu (2006) | Genetic algorithms and simulation to optimize the delivery schedule of Ready Mixed Concrete. | 13.8741 | 2009 | 2014 | | 28 |
| Tah and Carr (2001) | Framework for project risk knowledge management in the supply chain. | 12.3026 | 2004 | 2009 | | 5 |
| Briscoe and Dainty (2005) | Key principles to be followed if integration is to be achieved. | 11.4973 | 2007 | 2013 | | 0 |
| Tserng and Lin (2002) | Model of subcontracting and accelerated acquisition. | 11.1603 | 2003 | 2008 | | 5 |
| Khalfan, McDermott and Swan (2007) | Building trust among participants in the supply chain. | 10.9100 | 2010 | 2015 | | 2 |
| Voordijk, Meijboom and De Haan (2006) | Modularity in supply chains. | 10.0339 | 2009 | 2014 | | 0 |
| Love, Irani and Edwards (2004a) | Integration of design and project production processes. | 9.2250 | 2005 | 2012 | | 6 |
| Goodrum, McLaren and Durfee (2006) | Tracking system and tool inventory using RFID. | 7.8203 | 2008 | 2014 | | 3 |
| Love, Irani and Edwards (2004b) | Model to stimulate interorganizational relations and promote the formation of teams. | 7.5933 | 2005 | 2012 | | 12 |
| Wong (1999) | CSCM issues in total quality. | 6.7376 | 2004 | 2007 | | 6 |
| Chan <i>et al.</i> (2004) | Critical success factors for partnership projects. | 5.8806 | 2010 | 2012 | | 4 |
| Green and May (2003) | A critical perspective on construction reengineering. | 5.8398 | 2006 | 2011 | | 0 |
| Cheung <i>et al.</i> (2003) | Partnerships: cooperative hiring and behavioral aspects of the participants. | 5.6303 | 2010 | 2011 | | 4 |
| Beach, Webster and Campbell (2005) | Partnerships: progress in the construction industry and implications for suppliers | 5.3534 | 2010 | 2013 | | 4 |
| Arbulu <i>et al.</i> (2002) | Analysis of the value stream of a redesigned engineering supply chain. | 5.3019 | 2007 | 2011 | | 10 5 |
| Saad, Janes and James (2002) | Supply chain relationship management. | 5.1454 | 2008 | 2010 | | 6 |
| Fixson (2005) | Multi-dimensional framework that enables comprehensive product architecture assessments. | 4.4110 | 2007 | 2012 | | 0 |
| Hafeez <i>et al.</i> (1996) | Management information system: inventory management (minimum reasonable stock). | 4.1466 | 2000 | 2004 | | 39 |
| Fearne and Fowler (2006) | Applying lean principles to the construction industry: efficiency versus effectiveness | 3.8924 | 2010 | 2014 | | 15 9 |
| Bayliss <i>et al.</i> (2004) | Effective partnering tools in construction: a case study in Hong Kong. | 3.7517 | 2010 | 2011 | | 4 |
| Tah (2005) | Agent-based construction supply network modelling and simulation platform. | 3.4537 | 2006 | 2013 | | 43 |
| Tserng <i>et al.</i> (2005) | Supply chain management using bar codes and personal digital assistants (PDA). | 3.3629 | 2008 | 2012 | | 53 |
| Barlow <i>et al.</i> (2003) | Pre-assembly and standardization in home construction: lessons from Japan. | 3.2602 | 2006 | 2009 | | 0 |

More recent works tend to have weaker citation bursts. Except for Xue *et al.* (2005), the other references listed in Table 2 started their citation bursts at least one year after publication; e.g. Love, Irani and Edwards (2004a), Briscoe and Dainty (2005), Arbulu *et al.* (2002), Cheung *et al.* (2003), had a citation explosion started, respectively, 1, 2, 4 and 7 years after the publication of the article.

Partnership in construction is a recurring theme. Among the 25 references in Table 2, 4 refer to the partnership:

- (a) Chan *et al.* (2004);
- (b) Cheung *et al.* (2003);
- (c) Beach, Webster and Campbell (2005); and
- (d) Bayliss (2004).

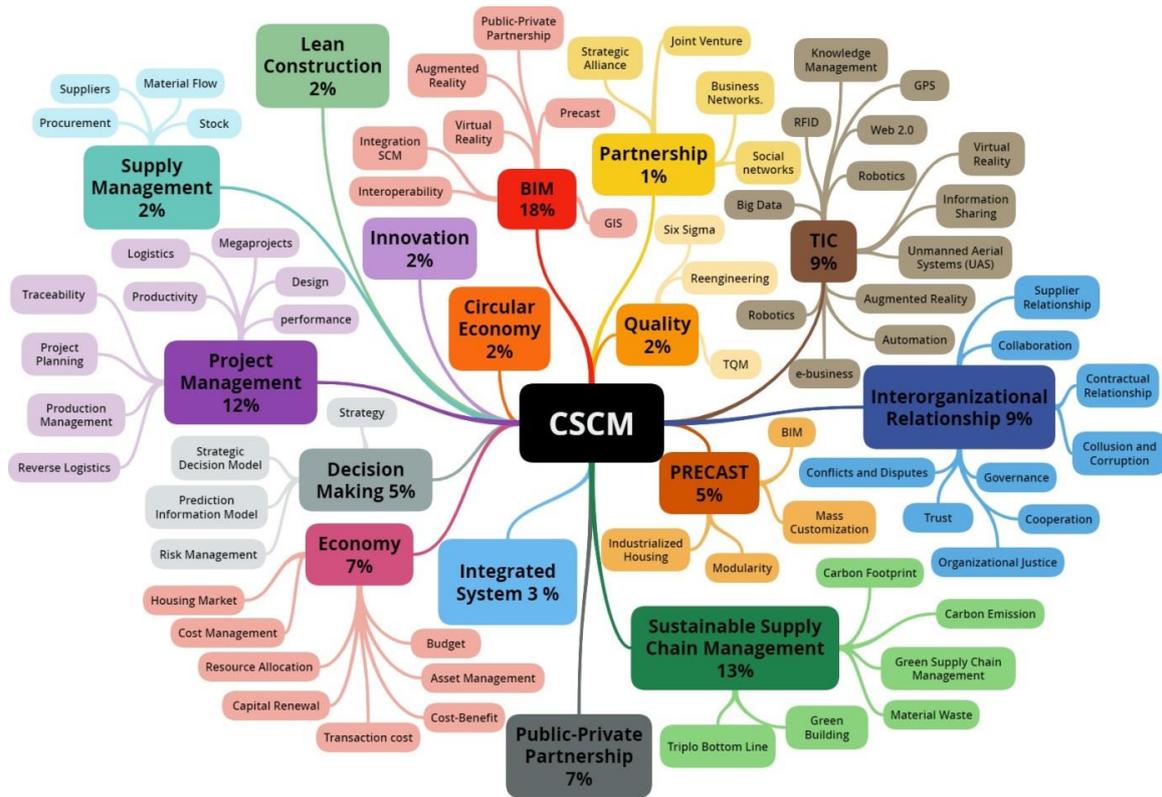
RFID, supply chain integration and relationship management are other themes that are repeated in more than one reference. Wang *et al.* (2007) e Goodrum, McLaren and Durfee (2006) dealt with RFID; Briscoe and Dainty (2005) and Love, Irani and Edwards (2004a) studied integration; and Love, Irani and Edwards (2004b) and Saad, Janes and James (2002) dedicated themselves to managing relationships in the construction supply chain. RFID and building trust, respectively in the works by Wang *et al.* (2007) and Khalfan, McDermott and Swan (2007), were the most recently consolidated themes (duration of time until 2015).

To track the recent development of knowledge, the 133 top references with the strongest citation bursts were considered and the first 10 that evolved until 2020 were listed (Table 3). The paper by Mathiyazhagan *et al.* (2013), which dealt with sustainable supplier selection initiatives, has the most current citation burst (extending until 2020), the longest lasting (4 years) and the strongest (11.5045). Research pertaining to sustainability/green chain (cluster #1), starting in 2016, saw an increase in demand (aroused greater interest), followed, starting in 2017, by BIM (#7) and structural equation modeling (#1).

Table 3 - Top 10 among the 133 top references with the strongest citation bursts in the period from 1998 to 2020

| References | Topic | Strength | Begin | End | 1998 – 2020 | # |
|--|--|----------|-------|------|-------------|---|
| Govindan, Khodaverdi and Jafarian (2013) | Sustainable supplier selection initiatives | 11.5045 | 2016 | 2020 | | 1 |
| Mathiyazhagan <i>et al.</i> (2013) | GSCM (barriers to implementation) | 10.8679 | 2016 | 2020 | | 1 |
| Eastman <i>et al.</i> (2011) | BIM handbook: a guide | 28.5065 | 2017 | 2020 | | 7 |
| Azhar (2011) | BIM (trends, benefits, risks, and challenges) | 25.8329 | 2017 | 2020 | | 7 |
| Bryde, Broquetas and Volm (2013) | BIM (benefits) | 21.4653 | 2017 | 2020 | | 7 |
| Eadie <i>et al.</i> (2013) | BIM (deployment) | 17.1228 | 2017 | 2020 | | 7 |
| Govindan <i>et al.</i> (2015) | Evaluation and selection of green suppliers | 16.8950 | 2017 | 2020 | | 1 |
| Yazdani <i>et al.</i> (2017) | Green supplier selection | 15.9842 | 2017 | 2020 | | 1 |
| Carter and Easton (2011) | GSCM: evolution and future directions | 14.6202 | 2017 | 2020 | | 1 |
| Hair, Ringle and Sarstedt (2011) | Structural equation modelling (theoretical criteria) | 23.9012 | 2018 | 2020 | | 1 |

Figure 8 - Concept map - search forward



Authors with search forward

Among the 484 works selected in search backward, 1,872 works related to the CSCM were identified. These works were classified into 19 areas. Figure 8 illustrates the representation of these 19 areas (with percentage of occurrence) and, when applicable, the internal details (description of the subareas). BIM (augmented reality, GIS, interoperability, integration and precast) corresponds to the area with the largest number of studies (18%), followed by GSCM (13%). New areas emerged (blockchain, social capital and construction 4.0) and others visibly intensified (project management, interorganizational relationship, public-private partnership and precast).

Discussion of results

To map the current CSCM research areas and subareas, searches were carried out for references backwards (in order to attain greater understanding of the origins and consolidation of areas/subareas) and for authors forward (to identify current areas/subareas – greater interest). Through the analysis of co-citations, representations of the structure of the CSCM were produced. CiteSpace® designed the co-citation networks (Figure 1). The data structure of WoS and Scopus, bases that encompass a diversity of quality documents from the AEC allowed the analysis of references, including the extension of the research to include books, journals and conferences from other bases.

According to the analysis of co-citations, in line with what O’Brien, London and Vrijhef (2004) refer to, the publication of the research on CSCM began in the middle of the 90s. Hafez *et al.* (1996) was the oldest work identified in this study. The summary of the main results linked to the questions (Q1 to Q5) is presented below:

(a) Q1 (research areas/subareas):

- 13 areas and 106 sub-areas were identified, according to the distribution shown in Figure 7;
- integrated system is the area that grouped the largest number of works (70);
- integrated system, decision-making and project-based supply chain are the oldest areas (average year 2004), while circular economy is the most recent area (2015);

- sub-areas related to BIM, partnership and integration are the most productive; and
- information technology, relationship and sustainability are the three major themes studied in the CSCM.

(b) Q2 (most active areas):

- the most active research fronts are highlighted in Tables 2 and 3;
- integrated system is the area that presented the largest number of topics of emerging interest; and
- partnership in construction, RFID, supply chain integration and relationship management are recurring themes.

(c) Q3 (key documents):

- key documents (relevant, therefore must-read documents) for each area are listed in Table 1. These documents, although they do not refer exclusively to the CSC, are highly cited in their respective areas or intermediate other studies;
- authors from the AEC industry refer to authors from other industries, which shows attempts to import and/or adapt concepts, theories, models and frameworks;
- non-specialized journals in the AEC industry also often publish articles on CSCM. In this study, we even identified only 8 specialized journals that published key documents;
- automation in Construction is the Journal that published the largest number of key articles (6);
- highly cited documents do not always arouse emerging interest (citation burst); and
- in general, the key documents analyzed have low centrality, which translates into low influence among the documents and the absence of revolutionary studies.

(d) Q4 (origin and development of areas):

- the timeline view (Figure 6) reveals the origin (beginning of connections) and the development of each area. Integrated system, e.g., appeared in 1998 and had a marked development until 2010;
- Figure 8 shows the current areas/subareas of greatest interest; and
- circular economy, sustainable supply chain management and building information are areas that have greater recent attractiveness.

(e) Q5 (promising areas):

- table 3 lists the topics related to two promising areas (of increasing interest): sustainable SCM and building information;
- other areas/subareas of increasing interest are represented in Figure 8. New areas have emerged (blockchain, social capital and construction 4.0) and others have visibly intensified (project management, interorganizational relationship, public-private partnership and precast);
- research related to BIM, sustainability/green chain, interorganizational relationship and structural equation modeling had a recent increase in demand;
- there is a certain predilection for the use of structural equation modeling techniques, such as the works of Hanseler, Ringle and Sarstedt (2015) and Hair *et al.* (2011); and
- there is a lack of studies on economic issues, blockchain, social capital and construction 4.0 related to CSCM, and are therefore fertile fields for the development of new works.

Conclusions

This article is a scoping review that followed the PRISMA-Scr recommendations to map the current areas and subareas of research in the scientific field of CSCM. The results show that CSCM has been continuously developing and attracting more and more researchers' attention. The number of documents produced (2,356 studies) and the diversity of related areas (forward search identified 19 areas, some of them emerging) support this discovery.

Based on bibliometric records (711,711 references), a systematic and comprehensive review of the existing global research status on the CSCM is provided. This study uses a bibliometric approach to analyze information with the help of CiteSpace[®]. The key documents and the main authors were identified; the

current situation and emerging points of interest in the CSCM field have been revealed. It also presented a panoramic view of how the main publications are distributed and networked, forming research areas and subareas. Moreover, this article establishes a knowledge base for future research, which can help scholars and managers to identify authors, documents and journals to be considered when dealing with a specific topic of CSCM. It also serves as a guide for future systematic reviews dedicated to revealing the progress of related research.

This research, therefore, in addition to providing a robust method of mapping the literature, can encourage the development of the CSCM, insofar as it serves as inspiration, consultation or a starting point for new studies. It also plays a key role in identifying the current focus of study and in discussing the future directions of CSCM. In fact, the expansion and deepening of studies on CSCM can benefit society as a whole, since improved management offers the opportunity to overcome challenges such as wasted resources, low productivity and excessive costs, time and conflicts.

The range of time covered (30 years – 1990 to 2020) and the removal of language and document type limitations (to include articles, proceedings and books), as well as comprehensive literature search, are an important strength of this study. Despite this, it is possible that research on CSCM also exists under different terminologies that were not captured in this review. The input data limit the present study. Other keywords can be included, removed and/or rearranged in future searches. Further analysis of the studies included in the review, using, e.g., a meta-analytical perspective, could provide more information. Future studies may focus on this meta-analysis.

The bases used to survey the raw data were WoS and Scopus. This limits research to the extent of these bases. Future research should consider the integration of other databases, such as Compendex (Engineering Village) and Engineering Database – Engineering Journals (PROQUEST).

The data supporting the conclusions of this article are presented in tables available at: <http://osf.io/zm4qh>.

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