Twenty-year application of logistics and supply chain management in the construction industry

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Abstract: The last decades have seen a growing interest in construction management amongst scholars, particularly, in how to apply supply chain management (SCM) strategies to improve logistics efficiency and project performance. Nevertheless, there is a lack of systematic literature reviews (SLRs) which integrate multiple quantitative methods to synthesise the literature on construction logistics and supply chain management (CLSCM) and analyse their trends during the last two decades. In this work, we concurrently deploy the rigorous six-step SLR protocol together with co-citation analysis, factor analysis, multidimensional scaling-based fuzzy *k*-means clustering, and keyword extraction and co-occurrence analysis to ascertain and examine the clusters of CLSCM application. The results show that there are six established research clusters in CLSCM, namely, logistics and SCM for prefabricated construction, construction procurement, construction supply chain integration, green construction SCM, reverse logistics in construction and onsite construction logistics. Amongst these clusters, construction supply chain integration plays the most integral role. Informed by this ascertained knowledge structure, we explore the research trends during the period reviewed, propose a conceptual framework for CLSCM and suggest research avenues.

Keywords: Construction; supply chain management; logistics; co-citation analysis.

1. INTRODUCTION

The construction industry, which is one of the most important sectors in terms of contribution to GDP and employment creation, and provision of housing, workplace and infrastructure (Burgan & Sansom, 2006; Durdyev et al., 2018; Oesterreich & Teuteberg, 2016), is known for its complexity and frequent underperformance (Le et al., 2021). This segment is characterised by high fragmentation, conflicting interests, low productivity, heavy cost and time consumption. According to Aloini et al. (2012), construction projects must contend with poor quality, overrun resources and overdue plans, which exacerbate problems in the industry. Key construction supply chain (CSC) actors include clients, designers, (sub)contractors, suppliers and consultants, who are all connected by information exchange, knowledge transfer, and contractual and financial relationships. However, their networks are fraught with unproductive collaboration; for example, a separation of design from construction, a lack of interfunctional cooperation and integration, and poor CSC communication (Behera et al., 2015).

The advantages of supply chain management (SCM) application in enhancing construction project performance have been recognised since the 1990s. Early research typically discussed the controversy about the applicability of SCM to the construction industry which differs from the manufacturing segment where SCM thrives. Since the 2000s, studies have focussed on analysing and exploring relevant SCM aspects in construction, notably after Vrijhoef and Koskela (2000) presented the vital roles that SCM plays in construction projects. This has inspired fellow researchers to undertake further research.

Awareness of SCM application during the last decades has evolved in construction. In the early 2000s, studies on construction supply chain management (CSCM) explored several perspectives on CSC integration (e.g., Dainty et al., 2001), examined the knowledge, skill set and attitudinal requirements for CSC partnering (e.g., Briscoe et al., 2001), and investigated the adoption of SCM in construction (e.g., Saad et al., 2002). Since the mid-2000s, several studies have been conducted to develop thorough frameworks for solving CSCM problems. Xue et al.'s (2005) agent-based framework for CSC coordination, Vaidyanathan and Howell's (2007) conceptual framework for mature CSCs and Chen and Ma's (2008) dynamic reputation incentive model for CSCM are some application examples. Recently, scholars have been interested in various integrated methods and tools for improving CSC efficiency and collaboration, including the adoption of lean principles (Eriksson, 2010), simulation-based logistics modelling (Vidalakis et al., 2011) and metaheuristic logistics optimisation (Kumar & Cheng, 2015; Said & El-Rayes, 2014). As a current trend, CSCM supported by Building Information Modelling (BIM) testifies to the concurrent progression of technological advances and digital transformation, and the application of logistics and supply chain management (LSCM) to construction (Le et al., 2020; Papadonikolaki et al., 2015).

To enhance CSC performance, business processes should be integrated according to the main

philosophies of SCM (Bengtsson, 2019; Ekeskär & Rudberg, 2016). Efficient CSCM plans must incorporate stakeholders to better share information and knowledge, which in turn develops trust and collaboration (Thunberg & Fredriksson, 2018). However, the operational benefits of information sharing are not equally salient across SC echelons (Domínguez et al., 2022; Nguyen, Adulyasak, & Landry, 2021), which implies that successful adoption of SCM principles in construction projects requires construction owners or main contractors to incentivise associated CSC actors to engage in their logistics reorganising initiatives (Ekeskär & Rudberg, 2016; Sundquist et al., 2018). However, the development of CSC integration has been inadequate and has proceeded at a slower pace than its counterpart in other industries (Le et al., 2020).

The lack of supply chain (SC) advances is a serious problem in logistics management for construction projects (Sundquist et al., 2018) given the industry's fast digital transformation (Dallasega et al., 2018). Prior research has acknowledged the difficulties in CSCM. For instance, a lack of SC actors' cooperation results in many issues related to information sharing and communication (Le, Dao, & Chaabane, 2019). CSC players' short-term benefit orientation prevents them from communicating up-to-date plans and knowledge to other SC stakeholders (Dainty et al., 2006; Gadde & Dubois, 2010; Love et al., 2004). Other examples include the deficiency of trust building and the late participation of CSC actors (Dainty et al., 2001; Thunberg & Fredriksson, 2018). Consequently, logistics practices in construction are lagging behind those in other industries (Segerstedt & Olofsson, 2010).

Thus, the last decades have witnessed a growing interest amongst construction management scholars in how to apply SCM strategies to boost logistics efficiency and project performance in construction (Dainty et al., 2001; Ekeskär & Rudberg, 2016; Eriksson, 2010; Le et al., 2020; Papadonikolaki et al., 2015; Sundquist et al., 2018; Thunberg & Fredriksson, 2018; Xue et al., 2005). Construction practitioners use certain methods and tools to make construction logistics more efficient whilst researchers are interested in exploring LSCM application trends (Le et al., 2020). It is thus important to acknowledge the research contributions during the last two decades to provide scholars and practitioners with further research avenues as well as the managerial implications for construction LSCM. Therefore, the first research question (RQ) in this paper was:

- RQ1: During the last twenty years, what are the construction logistics and supply chain management (CLSCM) application clusters that have been studied?

During the review process, we recognised LSCM application trends in the construction industry in the past two decades. Many reviewed papers focussed on site layout planning and material logistics (Kumar & Cheng, 2015; Le, Dao, & Chaabane, 2019; Said & El-Rayes, 2014; Song et al., 2017). Also, prefabricated construction LSCM have gained more publication and citation (Arashpour et al., 2017; Wang et al., 2018; Wang et al., 2017). In addition, scholars have paid attention to other topics such as CSC integration,

construction procurement, green CSCM and reverse logistics in construction (Ekeskär & Rudberg, 2016; Sundquist et al., 2018; Badi & Murtagh, 2019; Balasubramanian & Shukla, 2017a; Rahimi & Ghezavati, 2018; Zhai et al., 2017). However, there is a lack of papers focussing on summarising the LSCM application trends during the past twenty years. Aiming to provide researchers and practitioners with systematically reviewed trends in LSCM application, this paper thus attempted to answer the following question:

- RQ2: What LSCM application trends have been seen in the construction industry in the past two decades?

Scholars and construction managers need managerial insights for future research (Le et al., 2020) and practical applications of LSCM respectively (London & Singh, 2013; Sundquist et al., 2018). Therefore, a conceptual framework for CLSCM, which is based on analysing the previous frameworks of CLSCM, is needed to propose managerial insights and practical implications for researchers and practitioners. Despite significant contributions of previous frameworks to the CLSCM field (Cheng et al., 2010; Meng, 2010; London & Singh, 2013; Thunberg & Persson, 2014; Sundquist et al., 2018; Deng et al., 2019; Le et al., 2020; Wang et al., 2020), there is a lack of a conceptual framework using widely studied research themes to suggest managerial implications for construction project phases. Hence, our work also aimed to answer the questions below:

- RQ3: What are managerial implications for construction practitioners based on the developed conceptual framework?
- RQ4: What are research avenues for construction scholars based on the managerial implications?

To answer the research questions and fill existing gaps, we deployed the six-step SLR approach proposed by Durach et al. (2017) alongside quantitative methods (i.e., co-citation analysis, factor analysis (FA), multidimensional scaling (MDS)-based fuzzy *k*-means clustering,and keyword extraction and co-occurrence analysis) to achieve the following research objectives (ROs):

- RO1: Analyse contents of the literature and identify CLSCM application clusters over the last twenty years.
- RO2: Recognise LSCM application trends in the construction industry in the past two decades based on the identified clusters.
- RO3: Propose a conceptual framework based on the review results to provide scholars with managerial insights for future research and construction managers with practical implications for CLSCM.

The integrated application of six-step SLR and quantitative methods distinguishes our study and increases the reliability of the results. Following a strict procedure, we selected 591 relevant papers from 2324 search results. For the final analysis, however, we only retained 102 highly cited and consistently clustered articles published from 2000 to 2020. As earlier mentioned, we chose articles published from

2000 onwards because earlier research mostly debated whether SCM could be deployed in the construction industry which differs from the manufacturing sector. Since the 2000s, researchers have focussed on analysing and exploring relevant SCM concepts that have been studied for construction, particularly after Vrijhoef and Koskela (2000) explored the crucial roles of CSCM, inspiring fellow scholars to study the field. To ensure the reliability of the SLR process, we only included articles published in renowned journals. In keeping with the approach of Nguyen, Adulyasak, Cordeau, et al. (2021) and Le et al. (2020), books and other materials were excluded.

This paper is composed of five sections, beginning with the Introduction. The next section describes the deployed research methods, whose results are discussed in section 3. Based on the results discussion, section 4 presents the implications for research and practice whilst the Conclusion constitutes the last section of this paper.

2. RESEARCH METHODS

We followed the highly cited six-step SLR protocol of Durach et al. (2017), which was built on the synthesis of multiple prior SLR guidelines in the literature, including the influential approach of Tranfield et al. (2003), for the specific purpose of advancing SCM scholarship.

i. First, we developed the RQs along with expounding on the expected contributions and relevancy of this work (as in the Introduction).
ii. Next, the inclusion and exclusion criteria were specified.
iii. Then, we perused a sample of relevant papers to identify the keywords, database and search procedure.
iv. The most pertinent papers were shortlisted from the database search results based on the predefined inclusion and exclusion criteria.
v. From the chosen articles, we deployed co-citation analysis, FA, MDS-based fuzzy *k*-means clustering, and keyword extraction and co-occurrence analysis to synthesise the literature.
vi. Finally, a brief descriptive summary of the sampled literature was provided before we discussed the research themes ascertained.

We believe that the recency and SCM focus of this paradigm should strengthen the robustness and reproducibility of our SLR of CLSCM. Indeed, several literature reviews of CLSCM, e.g., by Badi and Murtagh (2019), Liu, Dong, and Shen (2020) and Yu et al. (2020), describe similar procedures with the same key elements despite each having a slightly different structure.

Where appropriate, we added details to the steps described above to reinforce the robustness of our SLR. In particular, we followed the recommendations of Liu, Dong, and Shen (2020) and Yu et al. (2020) to perform cross-referencing (also known as snowball sampling) on the bibliographies of the selected articles in order to retrieve other pertinent papers whose metadata did not mention our search keywords or that

were not included in our search database. Thanks to this technique, our paper was likely to retrieve more highly cited and relevant papers than many other recent CLSCM literature reviews (cf. Badi & Murtagh, 2019; Chen et al., 2021; Le et al., 2020; Wang et al., 2019).

Regarding the research articles indexed on the Web of Science (WOS), we saw few prior literature reviews that deployed co-citation analyses or bibliometrics for CLSCM (e.g., Liu, Dong, & Shen, 2020). Therefore, our work would be amongst the first endeavours to adopt this method for CLSCM literature reviews. Most importantly, our paper collated the literature clustering results by employing three clustering tools for data analysis triangulation, thereby enhancing the robustness of the results (Renz et al., 2018; Thurmond, 2001). Perusing prior CLSCM literature reviews to inform our SLR, we found that data analysis triangulation had not been commonly adopted in CLSCM literature reviews, meaning that our work would thus set a concrete example for enhancing the robustness of subsequent SLRs.

Since step 1 was completed in the Introduction, the next subsections will provide details for steps 2–6 of the applied procedure.

2.1. Inclusion and exclusion criteria

Following the SLR of Badi and Murtagh (2019), which was in line with other SLRs, we established the following inclusion criteria:

- Content focus: To collect the suitable papers, we leveraged the definition of SCM quoted by Vrijhoef and Koskela (2000) to define CLSCM as the management of the CSC via upstream and downstream connections including various entities, activities and processes that add value for ultimate consumers. The papers selected can focus on onsite tasks (e.g., site layout planning, onsite transportation and material handling) or offsite processes (e.g., material procurement and supplier selection), or the interface, transfer and/or integration between site activities and SCs (e.g., material delivery, reverse logistics, prefabrication, information sharing, process integration and stakeholder engagement) in line with the four roles of SCM in construction proposed by Vrijhoef and Koskela (2000).
- Time span: Published after 1999 and accepted for publication before 2021. Papers that had been accepted for publication before 2021, but that had not been available online before that time were not included in our sample because our work focussed on the literature available from 2000 to 2020. Year 2000 was the starting point of our literature retrieval because research has focussed on analysing and exploring relevant SCM application to the construction sector since that time (see the Introduction).
- Article type: (peer-reviewed) academic journal publication. In keeping with previous literature reviews (e.g., Le et al., 2020; Liu, Dong, & Shen, 2020), we only chose research and review articles in peer-reviewed academic journals for our work since such papers are deemed to provide verified

knowledge (cf. Ramos-Rodríguez & Ruíz-Navarro, 2004).

- Language: English.
- Search keyword: In the initial database search, only the papers that mentioned at least one of our predefined keywords in their titles, abstracts or keyword sections were filtered in.

For the exclusion criteria, we eliminated the articles that mentioned the keywords but did not relate closely to or focus intensively on CLSCM, including, for example, SC analysis of carbon footprint in the construction industry without regard to SC practices or strategies, lean construction without focussed discussion about logistics or SCM, and knowledge transfer in CSCs without explicit emphasis on its role in CLSCM. Papers that focussed on multiple sectors were also excluded, except for those that primarily compared LSCM in construction with that in another industry.

To reduce personal bias, the two authors of the present work applied the inclusion and exclusion criteria independently and cross-checked the two samples of selected papers to identify and resolve discrepancies. When both authors agreed to select a paper, we added it to the combined sample. Whenever a given paper was selected by only one author, we reassessed its relevancy to decide whether to exclude it. Afterwards, based on the set of excluded papers, we looked through the combined sample to double-check if there were any remaining publications similar to the excluded articles and discussed whether to retain or remove them from the selected sample to ensure consistent relevancy. This author triangulation helped minimise personal bias in the literature selection process.

2.2. Keywords and database

To obtain the pertinent literature, we used the WOS, which indexes more than "*100 million references from 33,000 journals*" (Martins & Pato, 2019) in English from leading publishers such as Elsevier and Taylor & Francis (Chadegani et al., 2013). This platform has been used by many scholars, such as Chen et al. (2021), Liu, Dong, and Shen (2020), Badi and Murtagh (2019) and Wang etal. (2019), for CLSCM literature reviews. Nguyen, Adulyasak, Cordeau, et al. (2021) searched multiple databases in their SLR, but the WOS still covered more than 90% of their selected sample, so we found it reasonable to choose this database for our literature retrieval. The keywords we used were ["*construction*" AND "*logistics*"] OR ["*construction*" AND "*supply chain*"] in the initial database search. We limited our search keywords to this set to keep the initial database search manageable. Nevertheless, in the snowball sampling step, terms related to LSCM (see Nguyen, Adulyasak, Cordeau, et al., 2021) were also accepted (e.g., supplier selection, supply management, procurement, purchasing, inventory control, transportation, site layout planning and material(s) management) given that such papers were highly cited by the CLSCM research selected in our sample and were thus likely relevant. In this step, journal articles that were not indexed on the WOS were also retrieved. We formatted their metadata in accordance with the WOS template.

2.3. Literature synthesis

There are several approaches to clustering reviewed literature (cf. Wang et al., 2016; Zhao et al., 2018; Zupic & Čater, 2015). In this work, we determined research clusters in the selected sample based on co-citation analysis (Small, 1973). Co-citation occurs when two papers are both cited by another study, and frequently co-cited papers are likely to share common research themes (Batistič et al., 2017; Small, 1973). Co-citation analysis is thus used to ascertain connected research themes in a sample of studies (Feng et al., 2017). Compared to bibliographic coupling, where the similarity of papers is evaluated based on commonly cited references, co-citation analysis is preferred because co-citation-based similarity is a time-variant indicator of many other researchers' opinions, whilst its measure in bibliographic coupling is time-invariant and solely indicative of the articles' authors (Wang et al., 2016; Zupic & Čater, 2015).

Albeit adopted in previous literature reviews (e.g., Wang et al., 2016; Batistič et al., 2017; Feng et al., 2017), this method has remained underutilised in CLSCM, with few examples, e.g., Liu, Dong, and Shen (2020), indexed on the WOS. In keeping with Liu, Dong, and Shen (2020), we used van Eck and Waltman's (2010) VOSviewer open-source software, whose latest version (version 1.6.18) was released on 24 January 2022. Compared to other techniques, this is a popular tool for mapping, clustering and visualising the literature (Xu et al., 2020; van Eck et al., 2010). Indeed, FA and *k*-means clustering can segment the papers selected, but with them, citation links between clusters are not visualised as effectively as in the VOSviewer.

We preprocessed the WOS metadata by Bibexcel (Persson et al., 2009) to prepare the co-citation matrix $\mathbf{C}_{|N|\times|N|}$ and input data for VOSviewer because this open-source software can output data for various bibliometric packages (Feng et al., 2017; Xu et al., 2018; Zhao et al., 2018). In co-citation matrix $\mathbf{C}$, $\mathbf{C}_{ii} = 1$; $\mathbf{C}_{ij} = \mathbf{C}_{ji}$ indicate the number of selected journal articles citing both references i and j. To ensure the adequacy of the citation data and the tractability of co-citation analysis (Zupic & Čater, 2015), we followed the four-citation threshold that Feng et al. (2017) proposed. This means that only selected papers with at least four in-sample citations were included in our cluster analyses. Nguyen, Adulyasak, Cordeau, et al.'s (2021) also adopted this threshold and presented well-justified clustering results. A further discussion of the justifiability of this threshold in our work is given in 3.2.1, where the clustering results obtained are reported.

For data analysis triangulation, we collated VOSviewer results by running FA in STATA 15.1 on the co-citation matrix compiled and fuzzy *k*-means clustering based on scikit-learn MDS (Pedregosa et al., 2011). In our FA, each item represented a paper and the latent variable capturing highly correlated items might reflect an overarching research theme. Structural equation modelling (SEM) was performed to analyse the convergent and discriminant validity of the latent variables (factors) determined.

We used MDS to project the co-citation matrix into a lower dimensional space, based on which *k*-

means clustering was run to segment the selected CLSCM scholarship. The correlation or cosine between each item in the co-citation matrix was input into the MDS (van Eck et al., 2010) in the scikit-learn library (Pedregosa et al., 2011) and the stress level of 0.10 was used as the threshold for MDS result selection, ensuring a fair goodness of fit whilst avoiding the high dimensionality of the resultant configuration of the projected space (Kruskal, 1964; Ramos-Rodríguez & Ruíz-Navarro, 2004; Zhao et al., 2018). Afterwards, we performed the fuzzy *k*-means algorithm (Khan et al., 2020) to cluster the referenced articles. The e-companion describes our implementation of MDS and fuzzy *k*-means clustering.

These tools have been used in other domains (e.g., Zhao et al., 2018; Wang et al., 2016), but in CLSCM, our work is amongst the first to employ all the three techniques for a systematic literature review. Our FA and fuzzy *k*-means clustering were strictly in accordance with Nguyen, Adulyasak, Cordeau, et al. (2021), but we attempted to improve the MDS procedure they used in the default settings. Indeed, we applied the gradient descent method to improve the MDS results so that the distances between items in the projected space better reflected their dissimilarities (see our e-companion). Also, our research design featured author triangulation and conceptual modelling, which Nguyen, Adulyasak, Cordeau, et al. (2021) did not conduct. Further, our discussion referred to both the cited and the citing literature to obtain more insights.[1]

The journal articles that were consistently assigned to the same cluster by all the three techniques were retained for thematic reporting, where we applied the PageRank-based algorithm of Wang et al. (2007) to determine key tokens in the title and abstract of each retained paper (see part B of Nguyen, Adulyasak, Cordeau, et al.'s (2021) supplemental material). In this step, we cleaned the extracted tokens to ensure consistency across documents. Next, the extracted tokens were added to the downloaded WOS metadata to compile the augmented metadata unless they were already mentioned in the keywords. The author-assigned and WOS-provided keywords were left intact. Thenceforth, we carried out VOSviewer keyword co-occurrence analysis of the augmented metadata and perused the papers retained in each cluster to identify its research theme (cf. Ikeziri et al., 2019; Zupic & Čater, 2015).

2.4. Result report

In section 3, we will present a descriptive overview of the selected journal articles that were published after 1999 and had become available online before 2021. We focussed our result reporting on the publications rather than on the scholars because only first authors are credited on the reference list in the WOS metadata. Influential papers in the selected sample were determined based on three indices, i.e., global citation index (measured on Google Scholar), in-sample citation index and PageRank, which are commonly used to measure research impact (Feng et al., 2017; Xu et al., 2018). Indeed, scholars often cite a publication when they find it useful to their research (Rao et al., 2013). Although citations cannot

[1] We would like to thank the reviewers for this suggestion.

measure an article's impact beyond academia, Halaweh (2018) argued that academic works that are valued by other researchers are likely to be of value to society and industry. Nonetheless, he noted that some researchers may cite certain papers to gain favour with editors or reviewers, even though they may not have read the papers or found them relevant. This concern can be partially addressed by the in-sample citation, which indicates the number of studies in our selected sample citing a particular reference. Since our selected sample represented the CLSCM literature from 2000 to 2021, this index highlights the impact and relevancy of a given study on the CLSCM scholarship during that period. By computing PageRank based on in-sample citation to assess the extent to which a study was referenced by highly cited CLSCM research (Xu et al., 2018), we can consider both the relevancy and the impact of the citing works. The fact that the citing articles influence subsequent research arguably substantiates the value of the original paper in opening fruitful research avenues. Nevertheless, these two indices cannot reflect a paper's influence on other disciplines, which is important for indicating the generalisability of its findings. Still, by discussing all three indicators, we could obtain a holistic view of the research impact of the CLSCM literature. A discussion about some alternative research impact measures is given in the e-companion.

2.5. Research design summary

Using the predefined keywords and applying the language, time span and document type specified in the Research Methods section as result filters on the WOS, we obtained a total of 2324 search results. One author read the metadata of the first 1499 papers and the other read the rest (see Figure 1).

Figure 1 caption: Literature retrieval, selection and synthesis procedure

Figure 1 alt text: Flowchart of literature selection process from database search through relevancy assessment and snowball sampling to clustering and thematic reporting.

Next, we cross-checked each other's shortlisted sample and re-evaluated each paper's relevancy based on our agreed-upon inclusion and exclusion criteria. After this step, we retained 406 papers and applied cross-referencing (snowball sampling) to their bibliographies to find other relevant journal articles that did not have our search keywords mentioned in their metadata or were not indexed on the WOS. Only the references with at least four in-sample citations (as recommended by Feng et al., 2017) were considered in our snowball sampling. After six iterations, another 185 studies were retrieved and we acquired a total of 591 papers in the selected sample, whose descriptive summary and analytical synthesis will be illustrated in subsections 3.1 and 3.2, respectively.[2]

3. RESULTS AND DISCUSSION

In this section, we present the literature retrieval and synthesis results and our discussions on the research

[2] The data were first collected in August 2020 when 472 relevant papers were selected after four snowball sampling iterations. As requested by one referee, other papers that were accepted for publication and became available online after that time but before 2021 were retrieved to complete the CLSCM literature from 2000 to 2020. Two additional snowball sampling iterations were conducted and a total of 591 journal publications on CLSCM were selected. This update did not qualitatively change the clustering results.

themes and insights for the CLSCM scholarship from 2000 to 2020.

3.1. Literature retrieval

Figure 2 presents general information on the selected sample. Most of the top countries, where data were collected for the selected publications, were western nations, i.e., the UK (75), Australia (34) and Sweden (29), followed by the US (28), Canada (16), the Netherlands (16), Finland (8) and Brazil (8) (Figure 2a). Five Asian economies appear in Figure 2a, i.e., China (52), Hong Kong (25), India (11), South Korea (9) and Malaysia (8). However, at the continent level, Asia (151) surpassed Europe (134) and America (52) (Figure 2b). For literature review-, simulation- and modelling-based research, where empirical data were not collected or artificial (e.g., simulated) data were deployed, we indicated "No Info" as the information source. Although less developed countries can arguably learn best practices from their more advanced nations, empirical research is needed to corroborate the cross-contextual generalisability of the research findings obtained in developed economies. The current geographical spread of CLSCM papers implies the need for more studies in developing nations. The number of published papers has significantly increased since 2015, which shows a recent trend of scholars paying greater attention to the field of CLSCM (Figure 2c).

(a) Countries of data collection (b) Continents of data collection

(c) Number of papers by publication year (d) Overview of research methods

Figure 2 caption: Summarised description of the selected sample

Figure 2 alt text: (a) bar chart of the number of CLSCM papers collecting data in a given country. (b) bar chart of the number of CLSCM papers collecting data in a given continent. (c) line graph showing more and more CLSCM research published since 2015. (d) bar chart of the number of CLSCM papers with a given research method.

Methodology has a central part in guaranteeing the validity and reliability of an academic paper. As can be seen in Figure 2d, top research methods employed by scholars in the CLSCM field are case study (212 articles), modelling (149), survey (117) and conceptual model (98). Since 2010, many authors have diversified the methods used to increase their research robustness. For example, several papers use the quantitative modelling and case study or integrated qualitative modelling, interview and survey mixed research methods. It is noteworthy that the wide use of case studies supports the claims in the preceding paragraph regarding the vitality of context in CLSCM and the need for further research in different settings.

Table 1 presents the top ten journals with the largest number of articles in our selected sample. These include Automation in Construction (58), Journal of Construction Engineering and Management (51) and Construction Management and Economics (41), which are top-tier journals that publish high-quality papers in the field of construction management. Of particular note is the appearance of sustainability-

focussed journals on this list, which indicates the increasing attention paid by construction scholars to environmental issues and sustainable development. Indeed, our analysis results, which will be discussed in the next subsection, show that construction scholars are publishing and citing ever more research on these topics, thereby establishing clusters of highly cited studies on how LSCM can improve the segment's environmental impacts.

Table 1. Top ten journals with the largest number of papers included in the selected sample

Table 2 illustrates the top ten cited papers by two different criteria, i.e., Google Scholar citation (proxy for global citation) and PageRank index. As can be seen, amongst the top ten globally cited journal articles, three also belonged to the top ten in-sample cited studies and top ten PageRank-based studies. Meanwhile, three of the top ten influential publications based on the PageRank index were also amongst the top ten in-sample referenced articles. Overall, the in-sample citation index correlated highly with the global citation (0.7939) and PageRank (0.7245) indices. The correlation between the PageRank index and the Google Scholar citations was only 0.6407. Even though globally highly cited research is not necessarily considered influential in its field of study (Feng et al., 2017), our selected sample of CLSCM literature showed that CLSCM studies highly cited by subsequent papers in the same domain also have a wide outreach in other domains.

Table 2. Top ten cited papers by different criteria

Amongst the three seminal articles which were all deemed most impactful according to global citation and PageRank indices in our sample was the case study of Vrijhoef and Koskela (2000) in Finland and the Netherlands, where the four roles of SCM in construction, including the interface, transfer and integration between site activities and SCs, were introduced and analysed. The other two seminal papers enriched our understanding of SCM in construction by conducting UK-based surveys to examine the success factors and barriers to CSC collaboration (Akintoye et al., 2000) and to procurement partnering (Black et al., 2000). These studies contributed to resolving the debate over the applicability of SCM to the construction sector in the pre-2000 literature and set foundations for subsequent research on LSCM application to this industry, which explains their consistently high ranking across different research impact measures.

In line with the summarised description of the selected sample (Figure 2), the UK was the most common country of data collection in the top ten globally cited papers (Baiden et al., 2006; Barlow, 2000; Meng, 2012), along with other developed countries, i.e., Australia (Love, 2002), Canada (Porwal & Hewage, 2013), Sweden (Dubois & Gadde, 2000) and Hong Kong (Chan et al., 2004). The widely used research methods were surveys (Chan et al., 2004; Love, 2002; Meng, 2012) and case studies (Barlow, 2000; Dubois & Gadde, 2000; Porwal & Hewage, 2013). Since SCM has broad and interdisciplinary scope (Swanson et al., 2018), the most highly cited research according to the global citation in our sample focussed largely on SC integration, including supply strategy (Dubois & Gadde, 2000), partnering and team integration

(Baiden et al., 2006; Barlow, 2000; Chan et al., 2004; Love, 2002; Porwal & Hewage, 2013). Given the discontinuity and temporariness of construction projects and the fragmentation of CSCs (Baiden et al., 2006; Barlow, 2000; Dubois & Gadde, 2000), insights, success factors, frameworks and impacts of integration and collaboration, which play an integral part in SCM (Mentzer et al., 2001; Min et al., 2019), are obviously interesting, both practically and academically. It can be seen that SC integration is applicable to not only the construction segment but also other industries. Thus, research findings from this group of articles on CSC integration can be cited by many papers.

In the group of the most influential papers according to the PageRank index, the UK continued to dominate as the country of data collection (Barker et al., 2000; Briscoe et al., 2001; Dainty et al., 2001; Hong-Minh et al., 2001). Apart from surveys and case studies, another commonly deployed method in this group was interview (Barker et al., 2000; Briscoe et al., 2001; Dainty et al., 2001). In addition to CSC integration topics (Briscoe et al., 2001; Cheng et al., 2001; Dainty et al., 2001), e.g., CSCM relationships (Hong-Minh et al., 2001) and partnering (Kumaraswamy & Matthews, 2000), CSC engineering (Barker et al., 2000) and materials management (Jaselskis & El-Misalami, 2003) were also studied in this group. These topics are especially vital in construction management (Ekeskär & Rudberg, 2016; Hammad, 2020; Le, Chaabane, & Dao, 2019). Unlike partnering, SC integration covers not only relationship development with partners (e.g., vendors and (sub)contractors) but also interfunctional integration and information-sharing systems (see 3.2.4). Our analysis demonstrated the central importance of CSC integration in CLSCM (see section 4), which explains why early papers that provided insights into CSC integration, e.g., common barriers and required skills (Briscoe et al., 2001; Cheng et al., 2001; Dainty et al., 2001), were highly valued in subsequent research. Yet, another reason for the high impact of this group of papers is their practical focus, with research ideas emanating from industrial actors (Jaselskis & El-Misalami, 2003; Kumaraswamy & Matthews, 2000) or research designs involving their collaboration (Barker et al., 2000; Hong-Minh et al., 2001). Therefore, readers learn not only new CLSCM approaches but also useful insights into their implementation in practical settings. It is such foci that mainly account for the high impact of the studies on other topics, i.e., CSC engineering (Barker et al., 2000) and materials management (Jaselskis & El-Misalami, 2003).

3.2. Literature synthesis results and thematic report

3.2.1. Literature clustering

We loaded the metadata of the 591 selected journal articles into VOSviewer, but only references with at least four in-sample citations were filtered in. We then identified six clusters of CLSCM research since 2000, as illustrated in Figure 3. In particular, in Figure 3, there were 965 references cited by a minimum of four of our selected papers, but those that were published before 2000 or unrelated to CLSCM were excluded from thematic reporting. In other words, only the 313 journal publications in Figure 3 that were

related to CLSCM, cited by four or more of our selected articles, and published after 1999, were considered for subsequent analyses.

Figure 3 caption: Clusters of CLSCM research determined by VOSviewer

Figure 3 alt text: Cluster 1 in green, Cluster 2 in dark blue, Cluster 3 in red, Cluster 4 purple, Cluster 5 in light blue and Cluster 6 in yellow.

Next, we performed FA in STATA 15.1 and fuzzy *k*-means clustering based on scikit-learn MDS to collate VOSviewer results before analysing each cluster's theme.

As regards FA, iterated principal factor analysis was first conducted on the co-citation matrix before factor rotation to determine whether the papers in each cluster could be captured by the same factor. In Table 3, which illustrates the result matches between VOSviewer and STATA FA, all items had factor loadings above 0.70 except for one in Factor 5 whose factor loading was only 0.65 but still acceptable (Dash & Paul, 2021). Overall, 108 studies were retained after VOSviewer clustering and STATA FA.

Table 3. VOSviewer and Factor Analysis results

We carried out SEM to assess the convergent and discriminant validity of the FA results (Fornell & Larcker, 1981; Sethi & King, 1994). Table 4 shows the consistency amongst the items captured by each factor as indicated by Cronbach's alpha exceeding the 0.70 threshold (Dunn et al., 2014). Based on the 0.85 threshold (Yu et al., 2018), these factors were not strongly correlated. Indeed, their squared correlations were less than their Average Variance Extracted (AVE) (Song, Zheng, et al., 2018). These measures indicate good discriminant validity. The convergent validity is indicated by the AVE and Composite Reliability, which are greater than 0.50 and 0.70, respectively (Fornell & Larcker, 1981; Yu et al., 2018). Indeed, the magnitude and statistical significance of the factor loadings also supported our conclusion regarding good convergent validity (Sethi & King, 1994). Hence, these six factors could be deemed robust.

Table 4. Convergent validity and discriminant validity analyses

The fuzzy *k*-means clustering algorithm (Khan et al., 2020) run on scikit-learn MDS-projected space (Pedregosa et al., 2011) determined a different number of clusters, but they mostly fitted the results of VOSviewer and STATA FA (see Table 5) with 102/108 papers consistently clustered. Therefore, we retained these 102 papers and six clusters for thematic interpretation.

Table 5. VOSviewer, Factor Analysis and MDS-based fuzzy *k*-means clustering results

Figure 4 illustrates the clusters with their retained papers by year of publication and in-sample citation. Noticeably, Cluster 6 achieved stable in-sample citations over time whilst Clusters 1 and 5 were referenced more often in the recent years by our in-sample papers since most of their articles were recent publications. Yet, Cluster 1's research experienced a larger rise in its in-sample citations than its counterpart in Cluster 5, notwithstanding their similar numbers of articles. Regarding Clusters 2 and 3, even though both of them

belonged to less recent literature, they followed different in-sample citation patterns. Cluster 2's studies accumulated quite stable in-sample citations throughout the period, whereas Cluster 3's research saw an increasing trend in its in-sample citations. Cluster 4 had the smallest number of retained papers scattered over the period concerned, but its recent in-sample citation growth may imply that this research topic received renewed interest from scholars. The theme(s) of each research cluster will be reported in detail in the next subsections.

(a) Research clusters by publication year (stacked graph)

(b) Research clusters by year of in-sample citation (stacked graph)

Figure 4 caption: Research clusters by publication and citation year

Figure 4 alt text: (a) the number of retained papers published in a given year is stacked by cluster. (b) the number of in-sample citations in a given year is stacked by cluster.

On a separate note, amongst the 313 selected papers with at least four in-sample citations, which were kept as vertices in our cluster analyses, one quarter (85) were published after 2014. Likewise, for the 102 retained papers whose clustering remained consistent across the three techniques the number was also around one quarter (25/102). This suggests that despite the inherent inability of co-citation analysis to identify emergent topics from very recent papers (Fahimnia et al., 2019), the proportion of publications from 2015 to 2019 was comparable to those from the preceding periods (2000–2014) in our results, indicating that many, though not all, recent papers were also retained with the threshold of four in-sample citations. Thus, this threshold, as recommended by Feng et al. (2017), can be considered appropriate in our case. Indeed, amongst the 313 selected articles with a minimum of four in-sample citations, 21.73% were cited by exactly four papers in our sample. The figure for the 102 retained papers was 11.76%, which implies that raising this threshold will reduce the contents covered whilst lowering it may not significantly increase the number of publications retained (in line with Nguyen, Adulyasak, Cordeau, et al., 2021).

Next, we read the 102 journal publications retained from our cluster analyses and deployed keyword extraction and co-occurrence analysis to determine the research topic for each cluster. The average publication year of the articles, whose metadata mention the coloured keyword, is specified on the bottom right corner of each figure depicted hereafter.

3.2.2. Logistics and supply chain management for prefabricated construction

This VOSviewer cluster consisted of 14 articles, half of which explicitly studied LSCM for prefabricated construction, which is part of industrialised construction (London & Pablo, 2017). Various prefabricated construction processes were examined in this cluster, e.g., supply management (Arashpour et al., 2017), materials logistics and project scheduling (Liu & Lu, 2018), green inventory control (Wu & Pheng, 2014) and CSC coordination and collaboration (Isatto et al., 2015; London & Pablo, 2017; Niu et al., 2017; Zhai et al., 2017). The other half of this cluster did not focus primarily on prefabricated construction despite

covering similar CLSCM topics, e.g., integrative/collaborative practices (Koolwijk et al., 2018; Kim & Nguyen, 2018), information sharing (Min & Bjornsson, 2008), BIM and SC partnering (Papadonikolaki et al., 2016), green CSCM (Balasubramanian & Shukla, 2018) and supply management for irregularly consumed materials (Jaśkowski et al., 2018). Nevertheless, the latter were often cited by our selected literature on LSCM for prefabricated construction (e.g., Luo et al., 2020; Luo et al., 2019) because they addressed the challenges of increasing uncertainty and complexity of material delivery and SCM engendered by prefabricated construction (Arashpour et al., 2017; Liu & Lu, 2018). Resolving such issues requires incorporating uncertainty into SC planning (Jaśkowski et al., 2018) and improving SC visibility via information-sharing and collaboration (Koolwijk et al., 2018; Kim & Nguyen, 2018; Min & Bjornsson, 2008; Papadonikolaki et al., 2016). Further, prefabrication is amongst the practices whose environmental and economic benefits have been explored in construction (Jaillon & Poon, 2008; Balasubramanian & Shukla, 2018). These reasons account for why these papers were captured by the same VOSviewer cluster. Based on the above discussion and the keywords depicted in Figure 5, we named this cluster "Logistics and supply chain management for prefabricated construction."

Figure 5 caption: Cluster 1 – Logistics and SCM for prefabricated construction

Figure 5 alt text: keywords co-occurring in Cluster 1's research with keyword "prefab*" in a grey box.

In line with the aggregate backdrop of commonly employed research methods in our selected CLSCM literature (see Figure 2d), case study and modelling were often adopted in Cluster 1's retained papers, some of which utilised case studies to test the proposed models (e.g., Liu & Lu, 2018) and help readers contextualise their applicability. Other scholars in this cluster also developed or deployed simulations to support analyses under multiple possible scenarios (e.g., Min & Bjornsson, 2008; Liu & Lu, 2018) or undertook surveys to obtain insights from many practitioners and organisations in LSCM for prefabricated construction (e.g., Koolwijk et al., 2018; Wu & Pheng, 2014). Overall, this cluster's modelling-based papers explored how to optimise LSCM for prefabricated construction under uncertainties arising from material pricing and substitution (Jaśkowski et al., 2018), lead times (Zhai et al., 2017; Liu & Lu, 2018), strategic purchasing preferences and multi-sourcing (Arashpour et al., 2017). Technologies for LSCM process and information integration were also studied in this cluster to facilitate decision making in prefabricated construction (Niu et al., 2017). Indeed, the key takeaway from this cluster's findings is the need for CSC coordination (integration) in prefabricated construction (cf. Arashpour et al., 2017; Liu & Lu, 2018; London & Pablo, 2017), which inspired our conceptual framework proposed in section 4.

As can be seen from Figures 4 and 5, this is a quite recent research cluster in that prefabrication has of late been increasingly implemented in construction thanks to its quality, productivity and environmental benefits (Liu & Lu, 2018; Wang et al., 2018) and recent technological advances for information sharing and processing in CLSCM (Demiralp et al., 2012; Wang et al., 2017; Yin et al., 2009). The geographical

spread of this cluster's papers (see the e-companion) reflects the dawning awareness of LSCM application to prefabricated construction in multiple countries. Yet, despite the rise in publications and in-sample citations in the last decade, this cluster's studies did not accumulate sufficient citations to rank amongst the top ten papers based on Google Scholar citation or on the PageRank index in our selected sample (Table 2). Nonetheless, we believe that this cluster will become more influential in the foreseeable future, given the current popularity growth in prefabricated construction.

3.2.3. Construction procurement

This cluster comprised 29 journal articles, which related to construction procurement with a focus on partnering as depicted in Figure 6, and whose primary research method was survey.

Figure 6 caption: Cluster 2 – Construction procurement

Figure 6 alt text: keywords co-occurring in Cluster 2's research with keywords "partnering," "construction" and "procurement" in grey boxes.

The construction sector is mostly characterised by one-off projects involving myriad parties with different or even conflicting interests, creating difficulties in developing trust, understanding and long-term relationships (Beach et al., 2005; Brown et al., 2001). According to Brown et al. (2001) and Naoum (2003), this characteristic, along with intense rivalry in price-based bidding and contractually-enforced relationships, accounts for the deficiency of traditional construction procurement approaches, where such crucial elements as value, quality, timeliness and innovation are overlooked in the tendering process and where (sub)contractors seek opportunities to compensate for their squeezed margin, resulting in adversarial procurement relations. Empirical insights into other drawbacks of traditional construction procurement can be found in the survey-based research of Black et al. (2000).

Since the 1990s, partnering has increasingly been deployed to address the inadequacy of traditional procurement approaches and ameliorate the construction industry's performance (Chan et al., 2003b; Yeung et al., 2008). The advantages of partnering in construction procurement were examined in the surveys of Black et al. (2000), Chan et al. (2003a), Beach et al. (2005), Fortune and Setiawan (2005) and Wood and Ellis (2005), and the top three commonly mentioned were better (less adversarial) relationships, improved quality, and reduced cost. However, it should be noted that the realised or perceived benefits of partnering in construction procurement differ across CSC echelons, e.g., clients, (sub)contractors and consultants (Black et al., 2000; Chan et al., 2003b; Humphreys et al., 2003).

Nonetheless, partnering as a construction procurement approach has traditionally been patchily implemented and underutilised (Phua, 2006). Despite the theoretically and empirically recognised interplay between the desired collaboration with suppliers/(sub)contractors and procurement practices (Humphreys et al., 2003; Kadefors et al., 2007; Eriksson & Nilsson, 2008), many construction clients have yet to adjust their procurement procedures accordingly (Eriksson & Laan, 2007; Eriksson et al., 2008;

Eriksson & Pesämaa, 2007).

Frameworks and management mechanisms for partnering in construction procurement were presented in Brown et al.'s (2001) conceptual model, Humphreys et al.'s (2003) case study and Lu and Yan's (2007) survey research. To determine whether to adopt partnering procurement in a construction project, several factors, including industry norms, competitive landscape, alternative partners available and their strategic significance in the focal firm's business, come into play (see Black et al., 2000; Phua, 2006). According to this cluster's survey results on construction procurement, the most commonly mentioned success factors in partnering were trust, equity, communication and understanding, collaboration and teamwork, and top management commitment (Black et al., 2000; Chan et al., 2004; Chan et al., 2003b; Kwan & Ofori, 2001; Ng et al., 2002; Wood & Ellis, 2005). These findings were drawn from several nations (see the e-companion).

Although published in the early 2000s, this cluster's research was stably cited by the subsequent studies on CLSCM selected in our sample (see Figure 4). As shown in Table 2, the studies of Barlow (2000), Black et al. (2000) and Chan et al. (2004) were amongst the top ten globally cited articles in our selected literature and Black et al.'s paper (2000) was also one of the most influential publications as per our in-sample PageRank index. This indicates the importance and relevancy of partnering in construction procurement, in particular, and CLSCM, in general. In our selected sample, Cluster 2's papers were often cited not only by subsequent construction procurement and supply management research works (e.g., Costa et al., 2019; Pesämaa et al., 2009; Eriksson & Westerberg, 2011), but also by CSC relationship and integration studies (e.g., Bygballe et al., 2010; Meng, 2010, 2012), whose cluster is of central importance in CLSCM (see 3.2.4).

3.2.4. Construction supply chain integration

The primary research topic of Cluster 3 is construction supply chain integration. Although Figure 7 shows that the key phrase "*supply chain*" commonly co-occurred with other keywords instead of "*integration*," our perusal of the 29 retained papers revealed that their contents revolved around CSC integration, which is reasonable as integration is the core of SCM (Mentzer et al., 2001).

Figure 7 caption: Cluster 3 – Construction supply chain integration

Figure 7 alt text: keywords co-occurring in Cluster 3's research with keyword "integration" in a grey box.

Given the fragmented nature of CSCs (Briscoe et al., 2001; Fearne & Fowler, 2006; Fernie & Thorpe, 2007), there have been numerous studies on CSC integration to boost construction performance (Bankvall et al., 2010; London & Kenley, 2001; Wickramatillake et al., 2007). Barriers to CSC integration in the UK were investigated in the interview-based research of Dainty et al. (2001). The case study of Bankvall et al. (2010) ascertained that coordinating sequentially interdependent activities as posited in traditional SCM recommendations is not suitable to achieve integration in CSCs, which epitomise reciprocal

interdependence. To help integrate intra-firm and inter-organisational processes within a CSC, Love et al. (2004) proposed a holistic CSCM model and carried out interviews with practitioners for model validation. Since information plays an instrumental role in SC integration, Titus and Bröchner (2005) established a framework for information management in CSCs.

To explore how CSC collaboration can be improved by lean thinking, Eriksson (2010) undertook action research in a case study of a global firm, where the lean approach was adopted for CSCM and yielded satisfying results. The integral techniques of lean management include concurrent engineering (Eriksson, 2010), an integrative product development approach, in which all product elements from conception through manufacture and logistics to usage and disposal are simultaneously considered, with a focus on customers and processes, and with all SC partners involved (Khalfan et al., 2001). Essentially, it is inadvisable to implement a lean CSC process without considering other entailed processes (Fearne & Fowler, 2006).

As improperly implemented partnering is a barrier to CSC integration (Dainty et al., 2001), this cluster's research also studied partnering to support CSC integration. Indeed, the survey and case study of Xie et al. (2010) showed that partnering can lift communication barriers and foster CSC collaboration. The process and skill set needed for developing SC partnerships were respectively explored in Errasti et al.'s (2007) action research and Briscoe et al.'s (2001) interview-based study. To assess the strength and development trend of a given CSC relationship, Meng (2010) developed a relationship assessment framework, which was validated through interviews and case studies in the UK. Relevant partnering literature was reviewed in the publications of Bygballe et al. (2010) and Gadde and Dubois (2010). Most of the papers retained in this cluster collected data in the UK (see the e-companion), and their citing literature in our sample, which also examined CSC integration, reported several findings from developed economies, e.g., Sweden (Dubois et al., 2019; Thunberg & Fredriksson, 2018), the UK (Meng, 2019) and the Netherlands (Papadonikolaki & Wamelink, 2017). This signifies the need to further examine CSC integration in developing countries (e.g., Kim & Nguyen, 2018).

It is noticeable that Cluster 2's publications also studied partnering, but they focussed primarily on procurement whilst this cluster overall covered broader contexts, from relationship development with SC stakeholders (e.g., suppliers and (sub)contractors) to interfunctional integration and information sharing systems. Its findings are valued not only for partnering in construction procurement (e.g., Eriksson et al., 2008; Humphreys et al., 2003), but also for other CLSCM subfields, for instance, SC visibility improvement for LSCM of prefabricated construction as previously discussed in Cluster 1 (e.g., Arashpour et al., 2017; Isatto et al., 2015). In fact, Cluster 3's papers were also cited by Cluster 4 – Green CSCM (e.g., Balasubramanian & Shukla, 2017a, 2017b) and Cluster 5 – Reverse logistics in construction (e.g., Chileshe et al., 2015; Hosseini et al., 2014). According to Zeng et al. (2018), reverse logistics is part of

CSC integration, which in turn has a positive impact on sustainable material use. This cluster is thus the core theme of our SLR, which will be explained in detail in section 4. Indeed, its in-sample citations accounted for the largest proportion in Figure 4 and Table 2 shows that many of the most influential studies in our selected sample belonged to this cluster (Vrijhoef & Koskela, 2000; Akintoye et al., 2000; Baiden et al., 2006; Briscoe et al., 2001; Dubois & Gadde, 2000; Dainty et al., 2001; Meng, 2012).

3.2.5. Green construction supply chain management

Noticeably, at the centre of Figure 8 is the thematic keyword of this cluster, i.e., "*green*" construction SCM. This cluster had only three retained journal articles, namely, Ofori (2000) and Balasubramanian and Shukla (2017a, 2017b), but its recent in-sample citation growth indicates its continued relevancy in CLSCM (see Figure 4) given the widely discussed environmental impact of construction (Ofori, 2000; Balasubramanian & Shukla, 2017a, 2017b).

Figure 8 caption: Cluster 4 – Green construction supply chain management

Figure 8 alt text: keywords co-occurring in Cluster 4's research with keywords "green" in a grey box.

As a company's environmental performance can only be as good as its suppliers', Ofori (2000) highlighted, in his literature review, the potential of SCM in ameliorating the greening of Singapore's construction industry via engaging in green purchasing and integrating all the parties involved in the construction process towards this common goal. This insight refers to CSC integration as discussed in subsection 3.2.4. According to Varnäs et al. (2009), environmental criteria seldom affected the bidding process because of a lack of knowledge or a fear for escalating costs. These studies were cited by Balasubramanian and Shukla (2017a, 2017b, 2018), who (in 2017a) collected survey data in the United Arab Emirates (UAE) and employed SEM to validate their conceptual model on green CSCM. Their findings (Balasubramanian & Shukla, 2017a) were in accord with the prior discussions of Ofori (2000) and Varnäs et al. (2009), showing the statistical significance of barriers to green practices, e.g., lack of engagement with SC partners, lack of knowledge and fear of rising costs, as well as the impact of green practice facilitators, e.g., certification, training and monitoring.

This cluster's publications were cited by other papers in our sample, which related not only to green, environmental or sustainable CSCM in other contexts, e.g., Indonesia (Wibowo et al., 2018), Italy (Pero et al., 2017), Malaysia (Bohari et al., 2017), Pakistan (Ali et al., 2020) and several developing countries (Ahmed et al., 2020), but also to sustainable construction in general, e.g., SCM of construction waste (Gan & Cheng, 2015) and reverse logistics (Chileshe, Rameezdeen, & Hosseini, 2016). Recent literature reviews of the research related to Cluster 4's theme can be found in the publications of Badi and Murtagh (2019) and Yu et al. (2020). It can be seen that green, environmental or sustainable CSCM has remained relevant over time around the world and that its increased in-sample citation in the recent literature indicates the increasingly recognised importance of sustainability in the field of CLSCM.

3.2.6. Reverse logistics in construction

There were 15 papers retained in this cluster, which all focussed on reverse logistics, the keyword connecting all other vertices in Figure 9.

Figure 9 caption: Cluster 5 – Reverse logistics in construction

Figure 9 alt text: keywords co-occurring in Cluster 5's research with keyphrase "reverse logistics" in a grey box.

In line with the discussion in subsection 3.2.5, construction exerts adverse effects on the environment, and reverse logistics provides one solution for it (Chileshe et al., 2015; Chileshe et al., 2016; Hosseini et al., 2014). In addition to sustainability/environmental concerns, CSC members implement reverse logistics, amongst other things, to meet regulatory requirements, earn reputations in local economies and save on costs (for other drivers of reverse logistics examined, see Hosseini et al.'s (2014) literature review and Chileshe, Rameezdeen, and Hosseini's (2016) Australia-based interviews). As demonstrated in Shakantu et al.'s (2008) case study in South Africa, combining material delivery (also known as forward logistics) and waste removal (or reverse logistics) allows optimising vehicle capacity utilisation, which translates into transportation improvement and unit cost reduction. Insights into how reverse logistics could fit into the government's stimulus for construction and demolition waste reuse and recycling in Brazil were introduced in Nunes et al.'s (2009) work.

Notwithstanding the incentives mentioned in the preceding paragraph, reverse logistics has been underutilised in construction as compared to its counterpart in manufacturing (Chileshe et al., 2016; Hosseini et al., 2014; Hosseini et al., 2015). Barriers to reverse logistics in Australia's construction sector were investigated in Chileshe et al.'s (2015) survey and Rameezdeen et al.'s (2016) interview. Comparing their results with the literature reviews of Hosseini et al. (2014), Hosseini et al. (2015) and Schamne and Nagalli (2016), we found that lack of government support, incentives or legislation, and escalation of cost were the most commonly mentioned barriers to reverse logistics adoption. In effect, they were two of the top-ranking barriers in the empirical findings of Chileshe et al. (2015) and Rameezdeen et al. (2016). Lack of SC partners' support is also a common barrier (Hosseini et al., 2014, 2015; Chileshe et al., 2015; Rameezdeen et al., 2016), which implies the need for CSC collaboration/integration to undertake reverse logistics. According to Chileshe et al.'s (2016) surveys and interviews in Australia, reducing waste generation and enhancing the understanding of the challenges and benefits of deconstruction are amongst the most important practices in promoting reverse logistics. Decision support models have been developed in this cluster's research to facilitate reverse logistics management (Aidonis et al., 2008; Chinda & Ammarapala, 2016; Rahimi & Ghezavati, 2018).

As indicated in Figures 4 and 9, this is a relatively recent research cluster, implying a growing trend of reverse logistics in CLSCM scholarship to produce positive environmental, economic and social effects

(Chileshe et al., 2015; Hosseini et al., 2015; Nunes et al., 2009; Rameezdeen et al., 2016; Shakantu et al., 2008). Recent examples of this cluster's citing literature, most of which also studied reverse logistics in construction, include Hammes et al. (2020) and Pan et al. (2020). Reverse logistics by definition entails moving used materials from the final destination, e.g., construction site, to another location, for reuse, recycling or disposal in an efficient or value-added manner (see Chileshe et al., 2015). Therefore, it is also part of green practices in green CSCM (see Balasubramanian & Shukla, 2017a; Badi & Murtagh, 2019). However, the formation of a separate cluster for this subdomain evidences its particular importance in CLSCM.

3.2.7. Onsite construction logistics

This cluster consisted of 12 journal articles retained, where optimisation models were deployed or developed for onsite construction logistics, where site layout planning plays an integral role (Figure 10).

Figure 10 caption: Cluster 6 – Onsite construction logistics

Figure 10 alt text: keywords co-occurring in Cluster 6's research with keyphrase "site layout planning" in a grey box.

Site layout planning is of paramount importance in the onsite productivity and safety of construction projects (Elbeltagi & Hegazy, 2001). Nevertheless, not all the proposed models, especially those in the less recent literature, explicitly took account of safety in their formulation (e.g., Easa & Hossain, 2008; Li & Love, 2000; Osman et al., 2003) as pointed out by Elbeltagi et al. (2004) and El-Rayes and Khalafallah (2005). More recently, most scholars have considered multiple objectives in their site layout planning models, including even noise (e.g., Hammad et al.'s (2016) mixed integer nonlinear program (MINLP)).

Axiomatically, normative modelling was the main research method in this cluster, and a variety of approaches were taken in the retained studies. Overall, genetic algorithms (GAs) were the most commonly used (e.g., Elbeltagi et al., 2004; El-Rayes & Khalafallah, 2005; Li & Love, 2000; Sanad et al., 2008). To visualise the site layout plan in the solution, Osman et al. (2003) integrated GAs with computer-aided design (CAD) software and presented their models with real-life data in Egypt. In the study of Elbeltagi and Hegazy (2001) in Egypt, temporary yet necessary facilities were localised by an artificial intelligence (AI) tool, i.e., knowledge-based system, and fuzzy logic was applied to assess the vagueness in their interrelationships before the GA-based search for an optimal site layout.

Other optimisation approaches that were adopted in this cluster include ant colony optimisation (ACO) algorithms (Lam et al., 2007; Ning et al., 2010), particle swarm optimisation (PSO) (Zhang & Wang, 2008), mathematical optimisation (Easa & Hossain, 2008) and approximate dynamic programming (DP) (El-Rayes & Said, 2009). Like the modified GAs aforementioned, these programs can be implemented in conjunction with fuzzy sets or simulation to take uncertainty into account. Examples can be found in the China-based study of Xu and Li (2012), where PSO was combined with fuzzy sets.

As an aside, onsite construction logistics comprises multiple processes, including materials handling and storage, onsite transportation, and site layout planning (Scheffer et al., 2016; Sundquist et al., 2018; Liu et al., 2020). Given the interplay between site layout planning and materials management on construction sites, e.g., material handling, storage and transportation (Liu et al., 2020; Said & El-Rayes, 2013; Scheffer et al., 2016; Song, Xu, et al., 2018), this cluster is often cited by material logistics research (Georgy & Basily, 2008; Spillane & Oyedele, 2017). In fact, several papers studied both site layout planning and material handling (Said & El-Rayes, 2013; Scheffer et al., 2016; Song, Xu, et al., 2018). Therefore, we named this cluster "Onsite construction logistics."

Moreover, the interdependences amongst logistics processes on construction sites imply that they likely benefit from CSC integration, which entails partners, processes, functions, etc., as discussed in subsection 3.2.4. In line with the CSC integration literature (e.g., Bankvall et al., 2010; Eriksson, 2010; Khalfan et al., 2001), Sundquist et al. (2018) proposed a framework which integrates actors, activities and resources to enhance the connection between on- and off-site logistics and boost construction performance. It should be noted that CSC integration is not synonymous with performing all logistics activities in-house. Indeed, prior studies have shown that outsourcing onsite logistics (using third-party logistics (3PL)) in a cooperative and well-coordinated manner can help improve efficacy by gaining access to partners' specialised resources and capabilities (Ekeskär & Rudberg, 2016; Le et al., 2021; Lindén & Josephson, 2013; Sundquist et al., 2018).

The steady publication and in-sample citation of this cluster from 2000 to 2020 (Figure 4) reflect its vital part in CLSCM.

4. IMPLICATIONS FOR RESEARCH AND PRACTICE

4.1. Conceptual framework development

To make a contribution based on our clustering of the CLSCM scholarship, we developed a conceptual framework for CLSCM (as presented in Figure 11), which shows that the clusters are important research streams in terms of impacting how and what CLSCM can be. The framework development followed three steps: (i) Analysing the previous frameworks for CLSCM to identify their contributions and limitations based on the highly cited articles (see Table 6); (ii) Using the six clusters identified to propose a new framework for CLSCM to overcome the limitations; (iii) Elaborating on the framework to provide scholars with managerial insights for future research and construction managers with practical implications for LSCM.

Table 6: Summary of previous frameworks for logistics and supply chain management

As presented in Table 6, most of the frameworks developed for LSCM follow the SC perspective, which focusses on advancing SC integration for logistics coordination and relationship building amongst SC actors (Cheng et al., 2010; Meng, 2010; London & Singh, 2013; Thunberg & Persson, 2014; Sundquist

et al., 2018; Deng et al., 2019; Le et al., 2020; Wang et al., 2020). Despite their significant contributions to the CLSCM field, there is a lack of a conceptual and/or practical framework using widely studied research themes to provide construction managers with managerial implications for construction planning, procurement and operations. Thus, our framework was established to cover the main activities of a construction project, consisting of three stages: (i) project planning and design, (ii) procurement, and (iii) construction execution (Babalola et al., 2019; Le et al., 2020).

The underlying articles, which we classified into six clusters, provided different levels of analysis (industry level, single supply chain level, company level and project level). However, our work aimed to propose a conceptual framework based on a review of the twenty-year application of CLSCM to overcome the limitations of the previous frameworks developed for the field. Our framework focussed mostly on the SC level, which advances the integration of SC actors to improve logistics performance. This approach is inspired by the studies of Meng (2010), London and Singh (2013), Sundquist et al. (2018) and Le et al. (2020). Following the SC perspective, we clarified the contributions of relevant SC actors (client, main contractor, designer, subcontractor and supplier) to SC coordination throughout project phases.

Figure 11 caption: Conceptual framework for construction logistics and supply chain management

Figure 11 alt text: "supply chain integration" in the outer circle. In the inner circle, the first column is for integrated planning and design; the second column for green procurement; and the third column for logistics and execution. These columns are connected by flow arrows.

As presented in the framework, the most important aspect of the application of CLSCM is SC integration (Cluster 3). It is thus placed in the outermost circle of Figure 11, indicating that it should cover all phases of each construction project. Next, green CSCM (Cluster 4) and reverse logistics (Cluster 5), which are connected to procurement and construction logistics, respectively, are considered important facets of construction practices. These aspects improve project performance and promote the sustainability of CLSCM. Indeed, an integrated CSC concerning green CSCM and reverse logistics has positive impacts on all activities across the three phases of a project (Badi & Murtagh, 2019; Bankvall et al., 2010; Chileshe et al., 2015). Details of the framework are presented in the following subsections.

4.2. Managerial implications of the conceptual framework

4.2.1. Project planning and design

Given the central importance of CSC integration (Figure 11), it should be considered from the planning and design phase of each construction project in order to allow appropriate practices to be incorporated and taken into account in subsequent phases. Moreover, an integrated CSC concerning green CSCM and reverse logistics is conducive to construction project activities (Badi & Murtagh, 2019; Bankvall et al., 2010; Chileshe et al., 2015). Consequently, CSC integration, green CSCM and reverse logistics must be considered in the planning

and design phase.

4.2.1.1. Supply chain integration for planning and design

The advancement of SC integration in construction has proceeded more slowly than its counterpart in other sectors. CSC capacity has merely reached the internal integration level which contends mainly with materials and resource management (Le et al., 2020). The construction segment often operates with labour hired from (sup-)suppliers and materials/components procured on a competitive basis. Thus, the industry structure is not conducive to the integrated and organised activities that SC integration requires (Bankvall et al., 2010; Fernie & Thorpe, 2007). However, during the last decades, scholars have shown SC integration or partnering as potential ways to deal with misalignment amongst CSC actors (Bankvall et al., 2010; Eriksson, 2010; Love et al., 2004; Xue et al., 2007). Applying SC integration to the construction sector needs effort from stakeholders. Bankvall et al. (2010) summarised the four conditions that SC players must meet for an integrated CSC. First, information exchange and data sharing across the SC need to be deployed at the early project stage with the participation of relevant actors, especially designers, (sub)contractors and key suppliers (Bankvall et al., 2010; Le et al., 2020). It is then essential to standardise innovation, quality control, risk mitigation and system alignment across SC partners (Bankvall et al., 2010). Next, efficiency is likely boosted by solutions that seek to increase prefabrication and pre-assembly (Bankvall et al., 2010). Finally, trust-building and mutual understanding are necessary for close relationships and collaboration amongst SC actors (Bankvall et al., 2010). Based on those conditions, to augment efficacy in waste elimination and process flow, the current CSCM trend leans towards external integration, which necessitates additional contribution and collaboration from CSC stakeholders (Dainty et al., 2001; Xie et al., 2010). From the SC perspective, relevant SC actors are recommended to improve logistics and project performance as follows:

- SC driver/coordinator: To coordinate the CSC, it is suggested that the client and/or main contractor be the SC driver who integrates relevant SC actors for project planning and design through information sharing and activity/resource planning (Venselaar & Gruis, 2016; Le et al., 2020). The client or main contractor (on behalf of the client) needs to mitigate issues caused by rigid contractual instruments and misalignment amongst CSC actors. Having relevant CSC members participate in project planning and design promotes working collaboration, trust building, mutual commitment and project efficiency. Thus, the risk of non-compliance amongst CSC actors can be eliminated (Bankvall et al., 2010). The SC coordinator needs to establish a meaningful culture change from adversarial to integrated planning and design (Eriksson & Pesämaa, 2007). Empirical research has shown the positive impact of client-led and contractor-led CSC initiatives on project performance (Jagtap & Kamble, 2020). To improve construction projects, SC drivers/coordinators should be empowered under the four conditions mentioned above by Bankvall et al. (2010).

Indeed, coordinating SC processes and participants requires communication, information sharing and information processing, so CSC drivers/coordinators should master relevant skills and tools to achieve CSC integration (van den Berg et al., 2020; Xue et al., 2005; Xue et al., 2007). Negotiation, contract arrangement, relationship building, cost sharing and side payment are also vital factors that SC drivers/coordinators should consider in order to support CSC coordination and integration (Kesidou & Sovacool, 2019; Xue et al., 2005; Zhai et al., 2017; Zhai et al., 2019). Further, clients and main contractors can entrust a 3PL provider with SC coordination to improve logistics performance and project efficiency as suggested by Bengtsson (2019) and Le et al. (2021). Albeit attempts to reorganise SC and logistics activities may increase costs, which may lead to the dilemma between potential benefits and extra expenses in some situations (Sundquist et al., 2018), savings can be realised thanks to effective implementation of prefabrication and lean management (Eriksson, 2010; Jaillon & Poon, 2008).

- Relevant SC actors: Efficient CSCM requires integrating other relevant actors (e.g., designer, key suppliers and subcontractors) early, especially from the stages of project planning and design (Bygballe et al., 2010; Gadde & Dubois, 2010; Le et al., 2020; Meng, 2010). As observed in existing practices, construction designers typically consider their structural and architectural designs without paying attention to logistics issues. Meanwhile, main contractors use their experiences to execute logistics activities in construction sites. By consulting key suppliers and subcontractors (about materials, parts supply and transportation services), the SC coordinator (main contractor and/or client) can ask designers to create productive designs which advance proper plans for construction activities. This helps the SC coordinator estimate the accurate project cost and prepare the appropriate schedule thanks to the resultant decrease in construction rework and uncertainties of material supply.

4.2.1.2. Planning for green construction supply chain management

In the last twenty years, scholars have applied the concept of green SCM to the construction segment to lessen environmental impacts and improve the value creation of the CSC (Balasubramanian & Shukla, 2017a; Ofori, 2000; Varnäs et al., 2009). Green CSCM practices not only focus on CO_2 emissions reduction, but also aim to lower production waste and expenses, as well as improve asset utilisation, innovation, materials reuse, competitiveness and stakeholder value (Badi & Murtagh, 2019). To achieve construction sustainability, SC actors are recommended to plan for green CSCM as follows:

- SC driver/coordinator (client and/or main contractor): All green SC processes and systems require a high level of collaboration, transparency and integration of relevant SC actors; thus, the SC coordinator is required to plan for green CSCM based on SC integration. Then, the SC coordinator must ask other relevant SC actors to participate in the green design, green procurement, green

logistics, green manufacturing, green operations, waste management and end-of-life management, which will ensure the successful application of green SCM (Badi & Murtagh, 2019). The SC coordinator is advised to establish strategic direction, planning, control, measurement, monitoring and evaluation for pertinent SC members to succeed in the green performance of the above-mentioned processes. However, the biggest challenge to green CSCM is not how to undertake it but how to have green CSCM prized by clients, even in the face of likely higher costs (Ofori, 2000; Varnäs et al., 2009). To facilitate green CSCM, the SC driver/coordinator needs to overcome the barriers, e.g., lack of engagement with SC partners, lack of knowledge and fear of rising costs (Balasubramanian & Shukla, 2017a), by cooperating with other CSC actors, e.g., designers and consultants, to leverage green practice facilitators, e.g., certification, training and monitoring. In effect, there is empirical evidence to show clients that such practices as prefabrication and lean management that can help achieve green CSCM can provide both economic and environmental benefits (Balasubramanian & Shukla, 2018; Eriksson, 2010; Jaillon & Poon, 2008).

- Other relevant SC actors: Green procurement and design call for other relevant SC stakeholders (i.e., designer, subcontractors and key suppliers) to participate at the beginning of the project. Green processes are associated with the strategic decisions of CSCM, so a lack of CSC integration can cause problems for project development. Green manufacturing, logistics and operations, waste management and end-of-life management require the involvement of SC actors, especially subcontractors and suppliers. The integration of these actors helps develop green tactical methods for prefabricated construction, onsite logistics and operations, and waste management (Balasubramanian & Shukla, 2017a; Ofori, 2000; Varnäs et al., 2009).

4.2.1.3. Planning for reverse logistics in construction

Researchers have shown that reverse logistics applied in construction can have many advantages, from positive environmental effects to economic and social benefits (Chileshe et al., 2015; Hosseini et al., 2015; Nunes et al., 2009; Rameezdeen et al., 2016; Shakantu et al., 2008). Whilst the environmental and social advantages of reverse logistics are fostered by governmental regulations, its economic benefits related to cost savings are the main motivation pushing construction practitioners to adopt reverse logistics (Hosseini et al., 2015). Reverse logistics application has become an emerging trend in construction projects; thus, there are calls for further qualitative and quantitative research to explore its benefits and leverage the roles of relevant CSC stakeholders. Together with green CSCM, reverse logistics should be planned at the beginning of the project with contributions from SC actors as follows:

- SC driver/coordinator (client and/or main contractor): The SC coordinator must follow government rules and take advantage of incentives for reverse logistics and waste reduction (Chileshe et al., 2015; Hosseini et al., 2015; Schamne & Nagalli, 2016) to motivate designers and

other relevant CSC actors to plan for and undertake reverse logistics. The SC coordinator can apply effective reverse logistics planning and design methods such as Aidonis et al.'s (2008) analytical methodological framework, Chinda and Ammarapala's (2016) decision-making procedure and Rahimi and Ghezavati's (2018) multi-period reverse logistics network design. The grave difficulty is to have clients value reverse logistics highly and pay for it. Indeed, SC drivers/coordinators may face the following barriers to reverse logistics: lack of SC partners' support (Chileshe et al., 2015; Hosseini et al., 2014, 2015; Rameezdeen et al., 2016), inadequacy of government incentives, support or legislation, and escalation of cost (Hosseini et al., 2014; Hosseini et al., 2015; Schamne and Nagalli, 2016). It is noted by Chileshe et al. (2016) that cutting waste generation and advancing the understanding of the challenges and benefits of deconstruction are amongst the most important practices in promoting reverse logistics. Empirical research has reported that firms undertaking reverse logistics in construction can benefit from government incentives, reuse salvaged materials or resell them (Chileshe et al., 2018).

- Other relevant SC actors: An integrated CSC with key actors (designers, demolition subcontractors and policy makers, as suggested by Hosseini et al., 2015) is required to implement effective approaches to successful reverse logistics. In (construction) reverse logistics planning and design, designers are considered important actors who determine the use of salvaged materials for new buildings. Furthermore, the practicability of reverse logistics in construction depends on the type of materials used for new buildings. To promote reverse logistics, clients (the SC coordinator) should ask designers to consider environmental protection as a priority (Hosseini et al., 2015). Moreover, governments need to consider reverse logistics as a mandatory measure to obtain environmental benefits. Also, regulations should support designers and contractors in eliminating the risks related to demolition and leveraging recovered materials for new construction.

4.2.2. Construction procurement

After project planning and design, construction procurement also has a crucial part in determining the success of construction projects. Owing to the complication of construction projects, procurement strategies must be flexible to meet relevant SC actors' requirements. Construction practitioners and scholars have used diversified procurement systems, which can be classified into four categories: separated, integrated, management-oriented and collaborative procurement. This categorisation follows Rahmani et al.'s (2017) approach to construction procurement analysis. However, due to the limitations of separated procurement, construction practitioners are advised to follow the other approaches (integrated, management-oriented or collaborative procurement) to practise green construction procurement. Applying these three procurement approaches is challenging and requires an integrated SC amongst relevant actors because a single SC player cannot change industry standards. Again, the four

conditions mentioned above by Bankvall et al. (2010) need to be satisfied for SC integration. Also, despite the recognised importance of quality and trust, suppliers and/or sub(contractors) that have successfully delivered high-quality performance and earned trust need not be the lowest bidder but should submit bids on a par with the market level to be reselected (Hartmann & Caerteling, 2010).

4.2.2.1. Separated procurement systems

The separated procurement method, also known as traditional procurement, is the most commonly used in construction, notably by inexperienced and occasional clients. In this system, completed designs lay foundations for inviting tenders and selecting main contractors. Clients or owners have the power to control the design process and set the final design; thus, the unchangeable design and construction costs are decided before starting the construction (Rahmani et al., 2017). Although traditional procurement has been widely applied, especially for government clients, the approach does not integrate the main contractor and subcontractors early in design and project planning. This can cause many project management problems, e.g., difficulty in building trust, communication and long-term relationships amongst project stakeholders (Beach et al., 2005; Brown et al., 2001). Traditional procurement systems leverage price-based bidding and contractually-enforced relationships where stakeholders only focus on their own benefits at the expense of project efficiency in terms of collaboration for problem-solving and assurance of total cost reduction (Black et al., 2000; Naoum, 2003).

4.2.2.2. Integrated procurement systems

Integrated procurement systems, also known as "design and build," use a main contractor as the central point of responsibility for the design, execution and delivery of the building on time and on budget. To practise green construction procurement, SC actors are recommended to make the following contributions:

- SC driver/coordinator: Being the design and building coordinator, the main contractor must possess the necessary skills and project management expertise to meet the client's requirements (Rahmani et al., 2017). In this procurement process, the client has a contractual relationship with the main contractor for both green design and delivery of construction projects. The main contractor can have in-house design and delivery teams or hire independent design and construction companies.
- Other relevant SC actors: Designers, subcontractors and key suppliers (belonging to construction teams) need to demonstrate their highly specialised expertise in green materials and execution methods and integrate them into the green design. This procurement integration thus helps reduce adversarial relationships and cost as well as improve construction quality (Chan et al., 2003a; Fortune & Setiawan, 2005; Wood & Ellis, 2005; Yeung et al., 2008). However, in this procurement strategy, construction project efficiency depends crucially on the main contractor's expertise and knowledge as well as on his perception of the benefits from partnering with other SC actors such as designers, key suppliers and subcontractors. Hence, more effort is needed from the main

contractor and relevant SC actors to have better SC integration and collaboration.

4.2.2.3. Management-oriented procurement systems

In a management-oriented procurement system, SC actors are recommended to have the following responsibilities in order to advance green construction procurement:

- SC driver/coordinator: The client signs a contract with a partner to manage green design and construction. This partner serves as a managerial expert on the client's behalf. This strategy is normally applied to clients who require manipulating the commencement and completion of the project as well as driving its planning and control (Rahmani et al., 2017). The client appoints a managerial expert to manage green design and construction activities on a professional fee reimbursement basis. Therefore, risks and responsibilities do not fall solely on a single main contractor. The managerial expert provides managerial expertise and has contractual relationships with the design team and subcontractors.
- Other relevant SC actors: The designer, subcontractors and suppliers are selected based on an agreement between the client and the main contractor. The managerial expert's responsibility extends to construction works. The primary benefit from this approach is its integration of designers, subcontractors and suppliers in green design and project planning. Having an external expert for construction management instead of focussing responsibility on the main contractor has become an emerging idea for project management (Ekeskär & Rudberg, 2016; Sundquist et al., 2018). This procurement approach is considered to promote long-term relationships amongst associated SC actors and reduce SC issues.

4.2.2.4. Collaborative procurement systems

Collaborative procurement, widely known as partnering, requires the involvement of all relevant parties (Eriksson & Laan, 2007; Eriksson & Nilsson, 2008; Phua, 2006). To facilitate green construction procurement, this approach requires SC actors to make the following contributions:

- SC driver/coordinator: The SC coordinator (client and/or main contractor) shall require all associated SC actors to participate in improving green project efficiency rather than work for individual gains (Eriksson et al., 2008; Eriksson & Pesämaa, 2007; Humphreys et al., 2003). This strategy is suggested to improve the inefficient processes managed by traditional procurement (Humphreys et al., 2003; Lu & Yan, 2007). Following this approach, the SC coordinator must prepare both internal and external conditions for collaborative green procurement.
- Other relevant SC actors: Regarding the internal conditions, relevant SC actors (designers, contractors and suppliers) need internal readiness assessment, which means reviewing and reorganising internal procedures and documentation (Rahmani et al., 2017). The external conditions consist of trust, equity, communication and understanding, collaboration and teamwork

amongst all relevant SC actors (Black et al., 2000; Le et al., 2020).

4.2.3. Construction execution

4.2.3.1. Logistics and supply chain management for prefabricated construction

SCM for prefabricated construction plays a vital role in improving project performance in terms of cost, quality and time. During the review process, we recognised that LSCM for prefabricated construction focusses on two main kinds of approaches: technological and managerial solutions (Arashpour et al., 2017; Im et al., 2009; Liu & Lu, 2018). Whilst the former apply advanced technologies for prefabrication, the latter concentrate on improving logistics management.

4.2.3.1.1. Technological approaches. In prefabricated construction during the last decades, advanced manufacturing technologies have been applied to produce complex and innovative prefabricated products (Demiralp et al., 2012; Wang et al., 2017; Yin et al., 2009). To leverage prefabricated construction logistics and execution practices, SC actors are required to make the following technological contributions:

- SC driver/coordinator: To improve prefabrication efficiency, the client and/or main contractor can ask designers and subcontractors to apply technological advances to their prefabrication design and implementation, including high-performance computing solutions to simulation and control, robotics, and innovative utilisation of composite materials (Arashpour et al., 2017). Recently, the most applied technologies in prefabricated construction logistics have been RFID and IoT (Internet of Things) (Demiralp et al., 2012; Wang et al., 2017; Yin et al., 2009).
- Other relevant SC actors: Designers, contractors and suppliers can establish RFID-based systems for precast design, production, inventory and transportation management. Using RFID helps these SC actors eliminate the time and distance gaps encumbering information exchange between the plant and office and improve quality control through instant tracking of relevant information on precast components and inventory. RFID and the IoT allow managers to quickly localise precast concrete (PC) components in the plant and check whether the schedule of PC components matches the construction schedule (Yin et al., 2009). Using RFID, cost savings can be obtained thanks to the decreased labour costs as well as the reduced number of remanufactured panels and transfers (Demiralp et al., 2012). Construction fabricators can also leverage the data-driven apparatuses and advantages of RFID in knowledge-based precast construction SCs as suggested by Wang et al. (2017) to reduce logistics operations time and inefficiency throughout the precast concrete SC.

4.2.3.1.2. Managerial approaches. The growing implementation of prefabrication and modular construction technologies has substantially increased the complexity of materials supply management in construction projects. Consequently, just like the applied technologies, the management of supply configurations is also critical for the improvement of prefabrication performance. During the past twenty years, scholars have applied multiple managerial processes to LSCM for prefabricated construction, such

as lean management, supply configuration, precast scheduling, disturbance evaluation and SC integration (Arashpour et al., 2017; Im et al., 2009; Liu & Lu, 2018; Wang et al., 2018; Zhai et al., 2017). To enhance prefabricated construction logistics and execution practices, SC actors are recommended to make the following managerial contributions:

- SC driver/coordinator: The client and/or main contractor can improve prefabricated construction by coordinating logistics processes with SC integration (Zhai et al., 2017). A coordination scheme should be established to solve the production lead time hedging issue in prefabricated construction and balance the delivery time required by the main contractor against the production time taken up by prefabrication subcontractors.
- Other relevant SC actors: Fabrication designers, subcontractors and key suppliers can combine the lean approach with the pull system to effectively control inventory for a temporary rebar assembly plant (Im et al., 2009). Applying the pull system and variability simulation has been proven to minimise inventory. To mitigate SC uncertainty, fabricators should consider supplier reliability and purchasing strategy to optimise supply decisions and configurations and include or exclude certain suppliers from the network (Arashpour et al., 2017). Further, prefabricated construction scheduling must take account of dynamic material logistics as an explicit constraint and consider the impacts of supply uncertainties on the project budget (Liu and Lu, 2018). Moreover, an operational and economic disturbance evaluation in a precast SC should be conducted to recognise SC uncertainties before precaution implementation, which facilitates the multiple disturbance management of precast SCs (Wang et al., 2018).

4.2.3.2. Onsite construction logistics

The application of onsite construction logistics has traditionally focussed on onsite layout planning and materials handling, which are closely interrelated (Le et al., 2019). Building construction necessarily entails adopting suitable construction technologies to facilitate the transportation, storage, assembly and arrangement of materials within a limited space. Processes on construction sites are normally related to materials handling, which cannot be strengthened without well-organised site layouts. A productive site layout enables smooth flows of materials and equipment, thus promoting the efficiency and safety of construction projects (Le et al., 2019; Sadeghpour et al., 2006). During the past decades, the integration of site layout planning and material handling has been considered for temporary facility planning to minimise materials logistics cost and maximise layout productivity. Integrated site layout planning can be described in two aspects: resolution (mathematical and knowledge-based techniques) and technologies (Le et al., 2019; Xu & Li, 2012; Said & El-Rayes, 2014; Kumar & Cheng, 2015).

4.2.3.2.1. Resolution. The research stream that applies mathematical algorithms to site layout planning has attracted the greatest number of scholars in the CLSCM field. In addition to quantitative objectives

(e.g., cost, distance and time), qualitative assessment (e.g., closeness rating, user preferences and safety rating) must be considered to devise an effective site layout. Several scholars have attempted to assimilate knowledge-based and mathematical techniques (e.g., Elbeltagi et al., 2001; Ning et al., 2010; Ning et al., 2016). To improve onsite construction logistics and execution practices, SC actors are required to make the following contributions:

- SC driver/coordinator: To improve onsite construction logistics efficiency, the main contractor is encouraged to apply mathematical and/or knowledge-based techniques for operations planning and implementation. Examples include AI-based systems to lessen the closeness weight amongst sites (Elbeltagi et al., 2001); fuzzy rule-based systems to evaluate facility proximity using both quantitative and qualitative attributes (Ning et al., 2010); a multi-objective dynamic site layout model to diminish transportation expenses and maximise distances amongst high-risk sites (Xu and Li, 2012) and a multi-attribute model to assess and choose site layouts based on managers' expertise (Ning et al., 2016).
- Other relevant SC actors: Based on the main contractor's mandate to use mathematical techniques for onsite logistics, engineering designers and/or logistics solution suppliers can develop mathematical models, such as GAs to assign temporary facilities to available locations (Li and Love, 2000); exact optimisation techniques to reach globally optimal solutions to static site layouts under many constraints (Easa & Hossain, 2008); approximate DP to minimise the total cost (El-Rayes & Said, 2009); MINLP to reduce transportation expenses and noise levels for various surrounding receivers (Hammad et al., 2016) and an optimisation framework to take into account both site layout (e.g., location, orientation and size of temporary facilities) and logistics (e.g., material delivery and resource planning) variables (RazaviAlavi & AbouRizk, 2017).

4.2.3.2.2. Technologies. Unlike the above-mentioned studies, some researchers have used advanced technologies to build data collection platforms for site layout planning. To advance onsite construction logistics and execution practices, SC actors are advised to apply the following technologies:

- SC driver/coordinator: To improve onsite construction logistics efficiency, the main contractor is recommended to apply technological advances for operations planning and implementation, including CAD, BIM, GIS (Geographical Information System) and/or RFID (Osman et al., 2003; Said & El-Rayes, 2014; Kumar & Cheng, 2015; Song et al., 2017).
- Other relevant SC actors: Based on the main contractor's demand that advanced technologies be used for onsite logistics, designers and/or logistics solution suppliers can develop a technology-based framework/platform for onsite operations, such as a CAD platform to visualise observations for site layout planning and increase site productivity through a reduction of the relative closeness weight (Osman et al., 2003); a framework to automate the collection of spatial and temporal project

data from multiple joint sources, e.g., BIM, in order to reduce the total logistics cost, including overheads related to site layout (Said & El-Rayes, 2014); a framework for dynamic layout planning using data from BIM to compute the facility size and dimension required (Kumar & Cheng, 2015); a decision-making approach to improve layout safety and cost using GIS to enable the formation and analysis of spatial and non-spatial data (Song et al., 2017), or an RFID real-time location system (RTLS) for site layout planning (Akanmu et al., 2016).

4.3. Trends and research avenues

Looking back at Figure 4, we can see that onsite construction logistics management (Cluster 6) has always captivated the interest of scholars over the past twenty years. Onsite construction logistics approaches can be broken down into the following: mathematical optimisation, knowledge-based approach and technological techniques. Subsequent research can focus on these three approaches to generate efficient site layout or materials logistics solutions. New algorithms combining both quantitative and qualitative attributes as well as AI for optimising onsite construction logistics can be developed in future studies. The digital transformation, with advanced technologies applied to onsite construction logistics, is also a promising direction for further research. As discussed in subsection 3.2.7, a few studies have been conducted on CSC integration and 3PL in logistics on construction sites (Liu et al., 2020; Said & El-Rayes, 2013; Scheffer et al., 2016; Song, Xu, et al., 2018; Sundquist et al., 2018), but more empirical research is needed to verify the realisation of potential gains from their implementation and propose proper measures to distribute the realised benefits fairly amongst all stakeholders.

The topic of LSCM for prefabricated construction (Cluster 1) has recently attracted many scholars for publication and citation (Arashpour et al., 2017; Wang et al., 2018; Wang et al., 2017) (see Figure 4). As mentioned above, the application of LSCM to prefabricated construction requires not only managerial approaches such as Lean and CSC integration (Cluster 3's theme), but also supporting technologies and tools, such as BIM, DfMA (Design for Manufacture and Assembly), RFID and GIS. However, the application of digital transformation (e.g., IoT, Big Data and AI) to LSCM of prefabricated construction during the last twenty years remains understudied. Thus, further research can focus on the implementation of digital transformation in LSCM of prefabricated construction. More investigation is also needed to examine how the digital transformation of prefabricated construction influences project performance, especially from economic, social and environmental perspectives that promote prefabricated construction in the first place. Since transporting prefabricated construction components to construction sites requires smooth coordination with onsite logistics to avoid workflow disturbances, research on connecting on- and off-site logistics processes is indispensable (Zhai et al., 2017; Sundquist et al., 2018; Liu et al., 2020) in prefabricated construction. The complexity and lead time of these interrelated processes on and off site pose risks to the material flow of prefabricated construction SCs (Luo et al., 2019). Our synthesis of the

citing literature (see the e-companion) revealed several publications on CSC risk management over the last two decades, but our clustering did not find a separate cluster this field of study. This gap suggests a fruitful avenue for more research on CSC risk management.

To improve construction procurement performance (Cluster 2), scholars have suggested CSC collaboration and integration (Cluster 3), e.g., with suppliers and subcontractors, as a lofty strategy. In fact, Cluster 3's research findings have been leveraged for Cluster 2's studies over the past two decades (see Figure 12). On the other hand, research on partnering in construction procurement provides great insights for CSC integration as partnering develops beyond dyadic relationships to incorporate multiple stakeholders and processes. 3PL has been suggested as a means to integrate relevant SC actors and reduce the total SC cost (Ekeskär & Rudberg, 2016; Sundquist et al., 2018). With 3PL providers' resources and capabilities, effective interfaces between CSCs and construction sites can be created. However, using 3PL is still a novel phenomenon in construction (Le et al., 2021), so more studies could be undertaken to explore the role of 3PL in CSC integration in order to raise the service level, technology adoption or sustainability of construction projects. With regard to technologies, e-procurement in construction is also a promising research theme as firms take advantage of technological tools for construction procurement and SC integration (Pattanayak & Punyatoya, 2020). Concerning research designs, our discussion in subsections 3.2.3 and 3.2.4 shows that empirical research has dominated Clusters 2 and 3; hence, more scholarly works based on modelling, e.g., forecasting, programming and optimisation, for supply management and CSC integration are clearly needed.

Figure 12 caption: Citation amongst retained papers

Figure 12 alt text: Cluster 1 in green, Cluster 2 in dark blue, Cluster 3 in red, Cluster 4 purple, Cluster 5 in light blue and Cluster 6 in yellow. The boxes are connected by arrows indicating citation relationships.

As illustrated in Figure 4, green CSCM (Cluster 4) and reverse logistics in construction (Cluster 5) follow an upward trend in recent studies (Badi & Murtagh, 2019; Balasubramanian & Shukla, 2017a; Rahimi & Ghezavati, 2018). To establish a sustainable CSC, construction managers need to think of new methods for green construction, including reverse logistics. In fact, a company's environmental performance can only be as good as its suppliers' (Ofori, 2000); therefore, CSC partnering and integration as studied in Clusters 2 and 3 also provide relevant directions for green CSCM and reverse logistics in construction. Figure 12 highlights the frequent cross-citations amongst these clusters. Additionally, as posited by Wang et al. (2018), prefab construction has the potential to improve productivity and reduce negative environmental impacts, which is why the knowledge base in Cluster 1 also offers vital insights into how to develop green CSCM. Future studies can thus explore developing managerial approaches or innovations for green procurement, design, prefabrication, logistics, operations, waste management and reverse logistics. Scholars can also focus on assessing the impacts of green approaches or reverse logistics

innovations on construction projects from an environmental, social, economic or technological perspective.

At the centre of Figure 12 is Cluster 3, which highlights the recognised importance of SC integration in CLSCM, e.g., to boost performance in prefab construction logistics (Zhai et al., 2017), relationships in construction procurement (Yeung et al., 2008), and effectiveness of green CSCM (Badi & Murtagh, 2019) and reverse logistics (Hosseini et al., 2015). Although the papers retained in Cluster 6 did not cite Cluster 3's research, onsite construction logistics clearly benefits from integration given multiple interdependent stakeholders and processes available onsite, e.g., site layout planning and materials handling (Song et al., 2019; Song, Xu, et al., 2018; Sundquist et al., 2018). However, the level of integration in CLSCM remains inadequate (Behera et al., 2015; Le et al., 2020). Technological advances are obviously conducive to CLSCM integration (Le et al., 2020; Papadonikolaki et al., 2015), which in turn supports construction procurement, reverse logistics and green SCM. These IT-driven integration topics have been broached in Clusters 1 and 6 albeit not extensively studied. Thus, more research on technology-enabled CSC integration and its benefits for CLSCM subdomains is highly recommended. As discussed in the previous paragraphs, research on other CLSCM subfields should emphasise integration to fully realise the expected benefits.

Finally, through SLR, this paper proposes a conceptual framework for SC coordinators and relevant actors to improve logistics and SC performance. However, the proposed framework only provides conceptual insights based on the SC perspective. We see that underlying articles provide different levels of analysis (industry level, supply chain level, company level and project level) for LSCM application. Thus, further research can be conducted to validate the framework and/or reflect the variation in analysis levels. By focussing on six important clusters mentioned in this paper, more studies can also develop practical frameworks for the implementation and evaluation of the performance of sustainable CLSCM. Given the criticality of context in CLSCM, we propose testing our conceptual framework empirically in multiple settings, especially in emerging economies because CSC integration, which has a central part in our framework, has been studied more intensively in developed countries.

5. CONCLUSION

This paper deployed the six-step SLR approach, where cross-referencing was employed to avoid overlooking relevant papers that were not indexed or included in the predefined database. Author triangulation was also adopted during the literature retrieval and selection step to reduce personal bias and ensure the relevancy of the journal publications selected for data analysis. Then, we utilised multiple quantitative methods, i.e., co-citation analysis, factor analysis and MDS-based fuzzy *k*-means clustering, as data analysis triangulation to robustly cluster the selected literature on CLSCM. Next, keyword extraction and co-occurrence analysis were performed, along with full-text perusal to analyse the contents.

We recognised that the application of CLSCM during the last twenty years can be divided into six clusters: Logistics and supply chain management for prefabricated construction (Cluster 1), Construction procurement (Cluster 2), Construction supply chain integration (Cluster 3), Green construction supply chain management (Cluster 4), Reverse logistics in construction (Cluster 5) and Onsite construction logistics (Cluster 6). These journal publication clusters informed our conceptualisation of a framework for CLSCM based on three construction phases, namely, planning & design, procurement and execution. CSC integration is the central part in our conceptual framework, which is substantiated by the cross-citations amongst the clustered papers. Further, we emphasised the need to take account of green CSCM and reverse logistics in construction phases.

We also explored these six clusters' trends during the twenty years of publication and suggested research avenues. Future research can focus on the implementation of digital transformation for LSCM of prefabricated construction. Further investigation is also needed to clarify the impacts of digital transformation of prefabricated construction on project performance. For SC integration and procurement, scholars can explore the role that 3PL plays in CSC integration to enhance the sustainability, technology adoption or service level of construction projects. Researchers can also attempt to develop managerial approaches or innovations for green procurement, design, prefabrication, logistics, operations, waste management and reverse logistics. Evaluating the impacts of green approaches and reverse logistics innovations on project performance in terms of environmental, social, economic and technological benefits is also a promising research avenue. Finally, for onsite construction logistics, further research can focus on mathematical optimisation, knowledge-based approaches and technological techniques to generate efficient site layout or materials logistics solutions. New algorithms combining both quantitative and qualitative attributes as well as AI for onsite construction logistics optimisation can be developed in future studies. Digital transformation with advanced technologies applied for onsite construction logistics is also a promising direction for further research.

5.1. Limitations

Despite our efforts to conduct a comprehensive SLR by using generic search keywords (i.e., "*construction logistics*" and "*construction supply chain*"), having author triangulation in the literature selection phase and double-checking clustering results using multiple techniques, this work still has limitations.

As the inherent weakness of co-citation analysis is its inability to identify understudied or emergent topics, notably those from very recent papers (Fahimnia et al., 2019), several research themes, e.g., CSC resilience (e.g., Abidin & Ingirige, 2018; Ekanayake et al., 2022) and 3PL (e.g., Ekeskär & Rudberg, 2016) did not appear in the retained results of our work although their papers were included in our sample. Still, this suggests that there is a lot of scope for future research endeavours in those CLSCM subfields.

Another limitation of this work is that only journal articles were reviewed. Although such papers are

deemed to provide verified knowledge (Ramos-Rodríguez & Ruíz-Navarro, 2004) and were commonly used in previous literature reviews (e.g., Le et al., 2020; Liu, Dong, & Shen, 2020), books and conference proceedings are also relevant materials that may enrich the overview of the synthesised CLSCM scholarship. Nevertheless, the peer review process of journal publication helps ensure that the published information we reviewed in this study is of high quality.

The papers we selected can focus on onsite tasks (e.g., site layout planning, onsite transportation and material handling) or offsite processes (e.g., material procurement and supplier selection), or the interface, transfer and/or integration between site activities and SCs (e.g., material delivery, reverse logistics, prefabrication, information sharing, process integration and stakeholder engagement) in line with the four roles of SCM in construction proposed by Vrijhoef and Koskela (2000). However, since SCM has broad and interdisciplinary scope (Swanson et al., 2018), we might have overlooked research on other processes which are related to CLSCM but not included in common LSCM keywords (see Nguyen, Adulyasak, Cordeau, et al., 2021).

Nguyen, Adulyasak, Cordeau, et al. (2021) searched multiple databases in their SLR, but the WOS still covered more than 90% of their selected sample, so we found it reasonable to opt for this database for our literature retrieval. In our snowball sampling step, we relaxed the requirement that articles be indexed on the WOS. Nonetheless, had we included more databases in our initial data search, the composition of the selected literature might differ significantly. Fellow scholars with access to other databases than the WOS may test the reproducibility of the sample reported.

Differences in citations of an academic work are ascribable to its age and field of study, and the number and seniority of its authors (Rao et al., 2013). Indeed, construction engineering & management research has lower average citations than other civil engineering subfields (El-adaway et al., 2019). Although dividing the citation counts by the publication age helps draw fairer comparisons with recent papers (Glock et al., 2019) (see the e-companion), further research is required to reasonably discount the impact of other factors (e.g., discipline, number of authors and author seniority) when comparing the research impact of scholarly articles. Also, albeit commonly used, the journal impact factor is an aggregate journal measure which is not necessarily reflective of the quality, content or value of individual papers.[3] Thus, more holistic alternatives should be evaluated and made widely available to facilitate research assessment.

5.2. Contributions

Our work makes several contributions to the construction management literature.

First, we ascertained the knowledge structure of CLSCM scholarship (Figures 3 and 12), which is defined as the network of relevant and co-cited literature undergirding future research (Nguyen,

[3] https://sfdora.org/2020/05/19/rethinking-research-assessment-ideas-for-action/; https://sfdora.org/2020/08/10/academic-research-culture-influences-learned-behaviors-in-graduate-students/

Adulyasak, Cordeau, et al., 2021; Samiee & Chabowski, 2012). This knowledge structure was supported by three clustering techniques, which evidenced the robustness of the results reported herein.

Second, given the central role of CSC integration and the recent positive trend in publication and citation of green CSCM and reverse logistics as previously discussed in the results, a conceptual framework for CLSCM was proposed to emphasise how these practices should be incorporated throughout a construction project.

Both fellow scholars and construction management practitioners can draw upon the knowledge base synthesised in this article.

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