Green Supply Chain Management in the Construction Industry: A literature review

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Abstract. The Construction Industry is considered one of the biggest waste generators in the world, and to tackle this problem, the concept of environmental sustainability in the construction sector can act in different areas, as waste reduction, carbon emissions reduction, better selection of materials and others. These areas involve several stakeholders during a life cycle of a project, therefore the implementation of a Green Supply Chain Management (GSCM) can help the sustainability aspect of constructions. The concept of GSCM has been already implemented with success in other industries, however the construction industry has its particularities that demands a specific methodology of implementation of these concepts, taking in consideration the differences between the sectors. To address this issue, a systematic literature review was conducted to find how the concept of GSCM can be implemented in the construction industry. This review covered 26 peer reviewed or proceeding papers in the last 10 years about the use of GSCM practices in the construction sector. The results were divided into four distinct areas of research: supply chain relationships, market competitiveness, life cycle and waste management. The biggest findings from this research is that to obtain better sustainable results, these practices must be implemented in the full life cycle of the construction, mainly on the design phase, when the selection of materials happen. Also, most studies found that government incentives are needed to make it more viable for companies to implement GSCM into their operations.

Keywords: green supply chain management, construction industry, construction life cycle, waste reduction, sustainable construction.

1. Introduction
With an increasing environmental concern about global warming, natural resources depletion, energy consumptions and others, the business environment is faced with a big change needed to combat these issues [1]. Several governmental and non-governmental acts have been made to reduce the impacts industries have on the environment. As a notable example, an international government agreement was sealed in the Paris climate conference (2015) that incorporated commitments on emissions, adaptation,
finance and transparency, demanding the signatory governments to provide legislatives or technical incentives for companies to implement green practices into their operations [2].

These green practices require that suppliers, manufacturers and customers work together within the supply chain to develop and implement better and more sustainable solutions for companies [3]. Within this idea, Green Supply Chain Management (GSCM) is viewed as a concept of management practices aimed at integrating environmental thinking into all the stages of a supply chain, including inbounding logistics, operations and reverse logistics [4]. The definition of this concept is very wide, ranging from green purchasing at the beginning of the supply chain into reverse logistics, to close the loop existing in this chain [5], as it can also improve the corporate image of the company in the market, helping it achieve higher profits, cost reduction and better business value [6]. Srivastava [6] defined GSCM as “integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing process, delivery of end-of-life management of the product after its useful life”, as this approach can range from reactive monitoring of the supply chain into more proactive practices as reverse logistics strategies [6].

Earlier, Sarkis [7] divided GSCM into three most important elements: (1) product life cycle influence, (2) operational life cycle and (3) environmentally influential organizational practices. The first of those elements involves life cycle of the product, that is largely influenced by its design phase, when designing the product with environmental issues in mind will play a big role. Second comes the operational life cycle, that accounts for how the organization operates in its business. The most important areas in this element for green practices are the procurement, production, distribution and reverse logistics. The last of the three elements is about waste reduction in the supply chain, as the five practices (reduce, reuse, remanufacture, recycle and disposal alternatives) aim to minimize the waste generated inside the supply chain. These practices are not only considered by organizations as a mean to reduce the environmental impacts of their activities, but also as a viable option to improve operational performance [8]. Other than improving performance, incorporating green practices into an organization’s operations can be viewed as a key business value [9], as it can help companies gain competitive advantage and increase their stock prices, making it more likely that these companies will adopt sustainable practices as a strategic imperative [10].

The concept of GSCM is wide enough to be used in different areas of business, however each area has its differences. In the construction industry, the complexity of the supply chain is different from the other areas, as it consists of a wide variety of stakeholders, as material suppliers, customer or user of the material, planner, contractor and owner, that are all involved somehow with the project [11], however a SCM aimed at the construction industry can help enhance efficiency and reduce costs and time [12]. Park et al. [13] stated that a successful Construction Supply Chain is the result of adopting strategies that take in consideration the differences from a traditional supply chain from the manufacture industry and the construction industry.

Therefore, this research is aimed at finding how the construction industry can implement a more sustainable supply chain in its operations, considering its differences from other industries. To achieve the objective of this research, a systematic literature review was conducted. The following paper is organized as follows. Section 2 explains how this systematic literature review was conducted. The results and discussions about the review are shown at Section 3. Finally, Section 4 brings the conclusion for this research.

2. Research methodology

The method used in this research is a systematic literature review, which according to Briner and Denyer [14] should follow the following principles: (1) review conducted systematically or through a method; (2) present a transparent method; (3) be replicable and updatable; (4) summarize and synthesize the main subject of the research. Through this method it is possible to develop a research that can bring the expected results in a systematic way, so it can be updated by other authors in the future, for an analysis of the development of the subject over the years.
Briner and Denyer [14] defined a protocol for the development of a systematic literature review, dividing into eight sequential steps that should be followed. Those steps are: (1) initial review, defining the problem that is intended to be studied; (2) definition of the objective, from the problem that was defined previously; (3) criteria for considering studies, defining the types of research that will be considered in this review; (4) strategy to obtain the studies, according to the databases; (5) eligibility, eliminating those studies that do not fit the defined requirements; (6) data collection, the manner in which the data will be obtained through the selected studies; (7) quality assessment method, to evaluate the quality of the data collected; (8) synthesize the results, the way in which the results of the collected data will be summarized. Table 1 shows the definition of these steps for this research.

| Steps                      | Research                                                                 |
|----------------------------|--------------------------------------------------------------------------|
| Initial review             | How the concept of GSCM can be applied to the construction industry       |
| Objective                  | Find applications of GSCM concepts inside the construction industry       |
| Criteria for considering studies | Papers that studied the use of GSCM methods in the construction sector |
| Strategy to obtain the studies | Research inside three databases (Science Direct, Scopus and Web of Science) for articles published in the last 10 years |
| Eligibility                | Peer reviewed papers and proceedings                                      |
| Data collection            | Exclusion of repeated articles, followed by reading the abstracts, then a complete read of the full paper |
| Quality assessment         | Articles analysed by the authors                                          |
| Synthesize the results     | Summary of all analysed papers divided into areas of study                |

2.1. Steps of this systematic literature review

The first step of this research was defining a problem that this research could help solve, that was if the concepts of GSCM can be implemented in the construction industry. Then, the objective defined was to find how these concepts can be used in this industry. The third step was defining the criteria for which studies would be contemplated in this research, resulting in only applications of GSCM concepts in the construction sector. Sequentially the strategy to obtain these studies was to initially search in three databases (Science Direct, Scopus and Web of Science), initially using the combination of key words "Green Supply Chain" or "Sustainable Supply Chain" and "Buildings" together, through the term "AND" and "OR" for first two terms, which resulted in a total of 229 articles. Another combination of key words was used, changing "Buildings" for "Construction Industry" or "Construction Site", also using the term "OR" to obtain better results, bringing 54 more papers for this review, in a total of 283 initial articles. The next step in this method was determining the eligibility of these articles, excluding all papers that were not peer reviewed or from conference proceedings, bringing the number of articles to 245. This step was then limited for results in the last ten years (considering that when this research was conducted, 2018 had not yet ended, therefore some papers may have been left out if they were published after this research was conducted), reducing the number to 234 articles. The following step was the data collection, initially eliminating all the repeated articles, reaching a value of 163. From this result, a title and abstract reading of all the articles found was made, selecting only those that fit the predefined characteristics type for this review, obtaining 34 articles. Then, a complete reading of the articles was made, eliminating those that would not be relevant to the review. In this last stage, 8 articles were eliminated, resulting in a final value of 26 articles analysed in this systematic literature review. Figure 1 summarizes this process. The seventh step in this method was the quality assessment of these papers, that was made in the selection of the databases and the selection of only peer reviewed and conference proceedings papers. This selection insured that these articles were relevant for this area of research in the construction industry. Finally, to synthesize the results, a summary of all the papers was made divided into four different areas of study.
2.2. Article analysis
The analysis of the results obtained through the articles selected for this research was divided into two parts. First, a descriptive analysis of the results of the selected articles was carried out, with a bibliometric analysis of the papers, finally dividing them in different areas of research inside the topic. In the sequence an analysis of the papers is carried, giving a summary of each of the papers included in their respective area of research, and a review of the concepts from Green Supply Chain Management that are mostly used in each area studied.

3. Results and discussion

3.1. Descriptive analysis
After the selection of the 26 articles, some analysis can be made regarding the origin of these articles. Initially, Figure 2 shows the amount of publications per year in this review. It is possible to see a constant increase from 2012, except 2015, of publications, something that shows that this topic is gaining interest in the research area of the construction industry.

Another possible analysis is about the country of publication of these studies, considering the main author in the article. Figure 3 shows the countries that most published in the set of articles selected for this review. The largest number of publications come from the United Kingdom, with 4. In a considerable number of the articles that were reviewed the situation of the country that the research was developed was considered, therefore the number of publications in the United Kingdom shows that they have great interest in this topic for their construction industry. Other countries that published more than once were China, Korea, Indonesia, Turkey, United Arab Emirates and United States. The main author with most publications is S. Balasubramanian with two papers. Four universities published two papers used in this review, Istanbul Technical University, Korea Advanced Institute of Science and Technology, Middlesex University and University of Sheffield, these last two from the United Kingdom.

A final bibliometric analysis was made about the methodology that was used in the reviewed articles. The most used method was Research (9). It was considered that a paper used a Research methodology when the main objective of the article was to develop a model or a methodology, maybe even using a case study to validate their model, but not as the primary goal of the paper. The articles that used Case Study (8) or Survey (8) were considered only those that the main objective was analyse the results from the case studied or the survey. There were also 2 articles that used a literature review. These results show that the papers in this area of research use a wide range of methods, not only focusing in one type.
3.2. Area of research analysis

To better analyse the articles in this review, they were divided in different areas of research inside the topic of GSCM in the construction industry. Table 2 indicates every paper that was classified in those areas. After that, a summary of each article is conducted to show the content of each paper.

Table 2. Articles published per area of research.

| Nº of Articles | Area of Research         | Authors                                                                 |
|---------------|--------------------------|-------------------------------------------------------------------------|
| 11 (42%)      | Supply Chain Relationships | Wnang et al. [15]; Wu and Low [5]; Abduh et al. [16]; Balasubramanian and Shukla [17]; Tang and Ng [18]; Kim et al. [19]; Woo et al. [20]; Olanezwaju, et al. [21]; Ghani et al. [22]; Chun et al. [23]; Mathiyazhagan et al. [24] |
| 7 (27%)       | Market Competitiveness   | Glass et al. [25]; Hsueh and Yan, [26]; Ketikidis et al. [1]; Tamosaitiene et al. [27]; Govindan et al. [28]; Zhang et al. [29]; Hafezalkotob [2] |
| 6 (23%)       | Life Cycle               | Cheng [30]; Elbarkouky and Abdelazeem, [31]; Dadhich et al. [32]; Nasir et al. [33]; Balasubramanian and Shukla [34]; Wibowo et al. [12] |
| 2 (8%)        | Waste Management         | Beldek et al. [35]; Akdag and Beldek [36]                                |

3.2.1. Supply chain relationships. Wnang et al. [15] conducted a research about the decision-making involved in the contractor and sub-contractor relationships in the construction industry. Wu and Low [5] conducted a survey with precast concrete companies from Singapore to understand the barriers in the stock management of the industry to achieve a green stock management in its supply chain. Abduh et al. [16] did a study case to evaluate a new assessment model developed by the Indonesian government to help achieve proper sustainable construction practices. Chun et al. [23] developed a research about the use of GSC practices in small and medium construction industries in Korea. Tang and Ng [18] conducted a survey about the sustainable building development in China, with senior managers of construction companies to find the biggest drivers and barriers in this area. Kim et al. [19] conducted a studied case in a major construction firm from Korea, to investigate the environmental capabilities of its different suppliers. Woo et al. [20] studied the communication capabilities between the contractors and suppliers in the CSC for companies in Korea, to understand how the information collaboration impacted the use of GSCM in these construction companies. Olanrewwaju et al. [21] studied how the use of sustainable practices in the CSC can affect the homeowners’ behaviours in relation to sustainability in operation phase of buildings. Ghani et al. [22] conducted an Economic Input-Output based Life Cycle Assessment (EIO-LCA) to identify the greenhouse gas emissions from the different areas of the CSC. Balasubruamanian and Shukla [17] conducted a research about the state of the use of GSCM practices in the construction industry in The United Arab Emirates. Mathiyazhagan et al. [24] developed a research to find the potential drivers for the use of GSCM in construction companies in India.
3.2.2. Market competitiveness. Glass et al. [25] conducted a survey to understand the construction industry preparedness to use Responsible Sourcing in the UK. Hsueh and Yan [26] developed an assessment tool to evaluate green innovations in the supply chain for contractors in the construction industry. Ketikidis et al. [1] developed a research about the performance of construction companies in Kosovo that used a GSCM. Tamosaitiene et al. [27] conducted a research about the selection of suppliers in the GSCM. Govindan et al. [28] developed a model to better evaluate the most sustainable construction materials for construction companies to choose in the search of a GSCM. Zhang et al. [29] created an interactive algorithmic method to reach a trade-off between economic interests from the construction companies viewpoint and the environmental protection from the government viewpoint from China. Hafezalkotob [2] studied the impacts that direct and indirect government interventions can have in the competition between green supply chains and non-green supply chains.

3.2.3. Life cycle. Cheng [30] developed a web service collaborative framework to measure and monitor carbon footprint in the supply chain of a construction project. Elbarkouky and Abdelazeem [31] conducted a literature review on GSCM, to discover its drivers and barriers for implementation in the construction industry. Dadhich et al. [32] conducted a Life Cycle Assessment for the supply chain of the plasterboard in one of the leading European material distributors, to find its carbon emissions throughout the supply chain. Nasir et al. [33] studied the differences and the impacts that a circular supply chain can have in achieving a GSCM in comparison to a linear supply chain in the construction industry. Balasubramanian and Shukla [34] developed a GSCM assessment framework to involving nine aspects of it: external and internal drivers, external and internal barriers, core and facilitating GSCM practices, economic, environmental and organizational performance implications. Wibowo et al. [12] conducted a literature review for the implementation of GSCM in the manufacturing industry to understand how it can help implement it in the construction industry.

3.2.4. Waste management. With the goal of reducing the generation of waste by the construction industry, The European Union Council published a waste management directive in 2008 to reduce it by 70% at 2020. To better understand how a GSCM can help a construction company achieve this goal, Beldek et al. [35] conducted a study case from Turkey. Akdag and Beldek [36] studied the integration of Green Building Design into the GSCM, to reduce the waste production in the construction industry.

3.3. Discussions

In this section, the findings from the articles analysed in this systematic literature review will be discussed, with each area of research being approached separately.

3.3.1. Discussion about supply chain relationships. Supply Chain Relationships was the area of research in this review that had the most number of publications, eleven, and is related about the relationships that can happen in the different stages of the supply chain. Most of the papers studied the relation between either the construction company and the material suppliers or the contractors and subcontractors, trying to understand how these relationships impact the use of a GSCM in the construction industry. The findings showed that to achieve a more sustainable supply chain the collaboration between the stakeholders involved in the supply chain needs to be better. More information about the environmental impacts that each material has needs to be better incorporated into companies’ decisions when buying materials. There also needs to exist better and consistent standards for the environmental capabilities of the suppliers. These standards need to come from the government, as well as more incentive for construction companies to adopt these types of materials.

3.3.2. Discussion about market competitiveness. This area of research is for articles that discussed the topic of how a GSCM in construction companies can help them obtain a competitive advantage or what is the impact in their finances when incorporating this type of management. With the seven analysed articles, it was noted that there are still a lot of belief that implementing a GSCM will bring more costs
than benefits. This problem is maybe the biggest barrier for the use of GSCM in construction companies, however some authors [1, 2, 16, 18, 24, 25] believe that this can be solved, as discussed in the last section, with more incentives from the government, helping small and medium companies to use more sustainable concepts in their supply chains, with benefits in cost reduction or tax reduction when using these materials or practices. The area in the construction industry that have best implemented GSCM concepts is the material suppliers [25], as they have more incentives from the government to develop more sustainable materials. This is something that can help more companies implementing GSCM concepts into their supply chains, with the government incentives that must happen, the construction companies will have better options to choose the materials that enter their supply chains.

3.3.3. Discussion about life cycle. This area of research was defined for articles that discussed the implementation or use of a GSCM throughout the full life cycle of a construction project. The biggest contribution from these six articles is the necessity to implement this sustainable supply chain in the different phases of a construction site, not only when selecting materials or the construction phase. In the design phase of a project, designers should incorporate more sustainable materials in comparison to the traditional ones. These materials should have a lower carbon emission and embodied energy in their life cycle and have the capability to be reused or recycled in the end of the life cycle. The construction phase should focus on minimizing waste generation, with a better collaboration of material information between stakeholders. The operational phase of a building can consume the most energy in its life cycle, so it is important that in the design phase better options for energy use should be implemented. Finally, the demolition phase, should also be affect by a better selection of materials in the design phase, with materials that can be reused or recycled, to dispose a lesser amount of waste into the environment.

3.3.4. Discussion about waste management. Although this last area had only two articles that focused solely on this topic, it was incorporated into the discussion of many more as a way of achieving a GSCM in the construction industry. The findings come to an agreement with what has already been discussed in the other areas, that better and more sustainable materials must be selected in the design phase. The use of these materials can help reduce waste production in the construction phase, as well as reducing the amount of material that needs to be disposed in the final stage of the life cycle of a building, reusing or recycling these materials, incorporating the concept of reverse logistics into the supply chain.

4. Conclusion

This review of the use of GSCM in the construction industry was carried out using 26 articles published in three different databases in the last 10 years. From these initial numbers was possible to realize that this topic of study needs more studies aiming at the construction sector, as the concept of GSCM is already incorporated in other industries but is only starting to be used in the construction industry. The articles that were analysed brought to attention the biggest barriers that exist for the implementation of GSCM practices in the construction sector, as the higher costs that this concept can bring to the companies. However, that is something that multiple authors cited that can be helped with financial incentives from the government, reducing costs or taxes to help small and medium companies to incorporate those practices into their supply chains.

Considering the findings of all four areas of research found in this study, they all point to the design phase as the most critical part of the life cycle to implement GSCM concepts to the companies. In this phase the selection of materials that are going to be used in the construction needs to happen taking in consideration the sustainability aspects of the materials, as the carbon and energy, and the capability of reverse logistics for these materials, reusing or recycling them to reduce the amount of material that will be disposed in the demolition phase of the building, reducing the negative impacts in the environment and helping achieving a more circular supply chain inside the construction industry.
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