

# GREEN SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION: A SYSTEMATIC REVIEW

The construction sector is particularly destructive of the natural world, in terms of resource and energy consumption and generation of waste. The industry itself, and construction research, are increasingly focusing on ways in which the construction process can become more environmentally sustainable. The concept of green supply chain management in construction (GSCMC) addresses the issue, following advances in green supply chain management in other sectors. However, a systematic review of scholarly work on GSCMC is unavailable and this paper aims to address the gap by providing a timely and thorough review of existing research. Applying the established method of Systematic Literature Review, an initial search yielded 207 papers, with a final set of 44 relevant peer-reviewed papers analysed in detail after systematic and transparent refinement. The field shows an increase in interest from 2012 and a more dramatic upturn in 2016 and 2017. Little attention has been paid to conceptual definitions or theoretical frameworks. The papers acknowledged different stakeholders but few considered how GSCMC may vary by role. An agenda for future research is proposed, including the need for end-to-end as well as detailed, subdomain studies, for different stakeholder perspectives and for addressing the challenges specific to fragmentation and potentially adversarial relationships in the industry.

Keywords: construction, green supply chain management, systematic literature review.

## INTRODUCTION

As a sector, construction extracts a heavy toll from the natural environment. The industry consumes enormous quantities of raw materials, produces prodigious amounts of waste and is responsible for a major proportion of global carbon emissions. Environmental sustainability in construction is a pressing concern for the industry and society globally (Kibert, et al., 2000). In response, sustainable or green supply chain management (GSCM) has much to offer. Complementing the burgeoning literature on GSCM in different sectors, practitioner and research interest in GSCM in construction is developing. However, the challenges for the construction sector are in some ways different from other industries and a systematic review of the application of GSCM in our sector is unavailable. The study presented here aims to address this gap by providing a timely review of existing research on GSCM in construction (GSCMC<sup>1</sup>). It contributes to the literature in its synthesis of work to date and proposed agenda for future research.

---

<sup>1</sup> In the discussion below, GSCMC refers specifically to green supply chain management in construction, whereas GSCM is used to refer to green supply chain management more generally.

The paper is based on a systematic review of the literature. The context for the review is first outlined by summarising the evidence for the environmental impact of construction and governmental and industry concerns. The method of systematic literature review (SLR) is then explained. A descriptive analysis of the literature is presented followed by a synthesis, both selective due to space constraints. Finally, an agenda for future research is proposed. The aim is to provide researchers with a consolidation of work done, and pointers to current weaknesses and gaps, that is, to describe the status of the field and to indicate areas not yet addressed.

The fifth assessment from the Intergovernmental Panel on Climate Change reports the built environment as a major determinant of energy demand (Lucon et al., 2014). The sector is recognised as heavily dependent on extraction of raw materials (European Commission, 2008). Construction and demolition waste constitutes one of the highest volume waste streams in the EU, generating between a quarter and a third of all EU waste (EU, 2015). Its high consumption of resources and energy, in delivery of the built environment and in operation of buildings and infrastructure thereafter, and its generation of heavy, voluminous and mixed waste contribute to the construction sector's particularly negative environmental impact. This impact is exacerbated by the long term nature of the final product: today's buildings and infrastructure 'lock in' energy consumption over the next decades (Lucon et al., 2014) and represent a potential legacy of future waste. National and regional governments worldwide have recognised the challenges and are reacting with tighter legislation (cf EU waste reduction) and initiatives to lead by example. The industry too has begun to address the challenges, with over 70 national Green Building Councils working to offer leadership and co-ordination. Environmental performance assessments such as BREEAM and LEED are increasingly applied to new developments and innovation on materials continues. However, the character of construction as a fragmented industry remains an issue, and the need for systemic approaches and collaboration within and across sectors in the construction supply chain has been proposed as crucial for more rapid progress. The domain of green supply chain management (GSCM) offers such a systemic and collaborative approach. GSCM then is critical to facilitating more sustainable construction and reducing the sector's negative impact on the natural world of today and tomorrow.

Before describing the method for the research, it is important to clarify the primary term and distinguish it from concepts with which it is sometimes confounded. At this point, the definition is necessarily high-level - in the discussion below, we consider the definitions in the literature, offer a more rigorous formulation and discuss the challenges of definition. GSCM is initially defined as activities aimed at reducing the environmental impact of the supply chain for the built environment. It is differentiated from sustainable supply chain management, a broader concept which incorporates economic and social sustainability as well as environmental (Ahi and Searcy, 2013). The aims of GSCM also differ from those of lean supply chain management (SCM): lean principles address the identification and managing out of waste with the objectives of increasing efficiency, lowering cost and providing improved value to the customer (Banawi and Bilec, 2014). The objectives of GSCM centre on environmental performance.

## **METHOD**

A systematic review of a research literature is a critical appraisal of previous studies conducted using a methodical and transparent process. Originating in the field of

health as a method offering a rigorous approach to the synthesis of empirical data, SLR is increasingly widely applied in a broad range of domains where a thorough and comprehensive review can contribute to knowledge (Briner and Denyer, 2012). The systematic review differs from a non-systematic or expert review in its explicit recording of all decisions pertinent to the review. Beginning by mapping the territory in an explicit manner, the systematic review then attempts critically to examine the included studies and synthesise the findings into a coherent account of the field. The current paper is aimed at consolidating existing knowledge for the research community. The method can also be used to distil empirical evidence for practitioners, and the practical insights from the GSCMC literature are discussed elsewhere in a longer version of this paper (in preparation).

Following the stages set out in Gough et al., (2012), Table 1 summarises the protocol for the current review. The objective of the review was to evaluate the status of the field and to identify directions for future research.

In order to ensure high quality, only papers from peer-reviewed journals were selected. In determining whether a paper addressed GSCMC, decisions on inclusion were challenging given the fuzzy boundaries of the topic. The guiding rule applied was that, for inclusion, the research or discussion had to cross stakeholder boundaries or consider the perspectives of different supply chain actors. The default decision was inclusion if the paper was found from the search terms specified, as the original authors deemed their work as relevant to GSCMC through their choice of keywords or phraseology. Papers that addressed any aspect of construction were included, whether focused on a specific sub-sector such as road maintenance or construction more generally.

*Table 1: Systematic review protocol based on Gough et al. (2012)*

Stage	Description	Detail
1	Define the research questions	What is the status of research on GSCMC? What are the key insights?
2	Define the exclusion/eligibility criteria	Paper in English in peer-reviewed journal. Published before 31st August 2017. Paper topic is green supply chain management Paper focus is the construction sector
3	Define search terms and sources	Search terms: supply chain AND (green OR sustainable) AND construction IN subject Sources: a proprietary metadata integrator (Primo Central Index supplied by Ex Libris) which receives data from over 500 sources, including Scopus and Web of Science
4	Search, screen and compile set of included studies	207 papers found; 163 excluded, of which 14 duplicates; 44 papers in final set
5	Analysis: code and critically evaluate included studies	Thematic analysis: deductive based on coding structure; then inductive critical evaluation
6	Formulate synthesis	Thematic synthesis: deductive based on analysis by codes; inductive critical evaluation

To ensure rigour, both authors independently conducted the search and assessed the papers for inclusion in two stages: (a) reviewing title, keywords and abstract; (b) skim reading of the paper. At each stage, any discrepancies were discussed and if not resolved, the paper was included in the next stage.

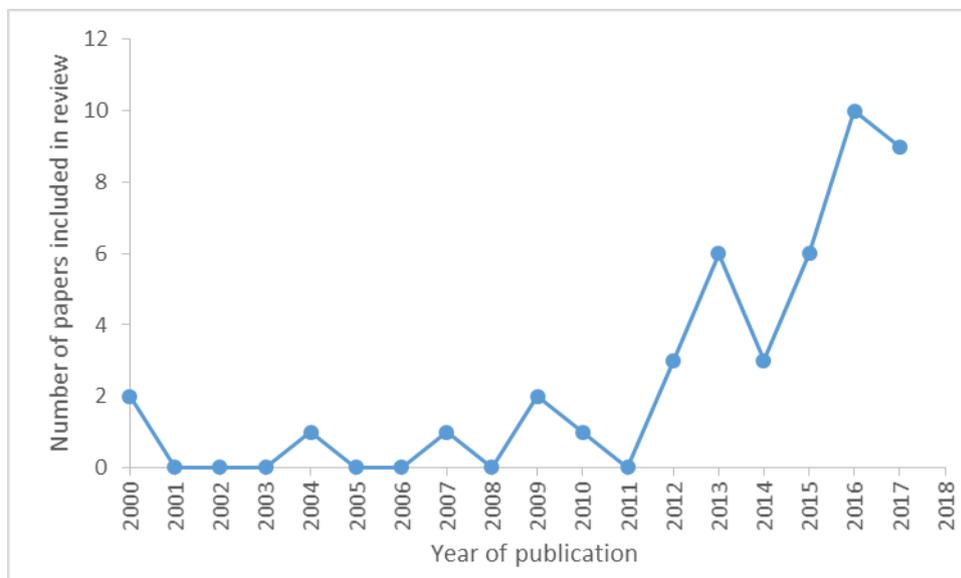
The a priori coding structure comprised: focus (specific subdomain or industry generic), aim, method and findings. Emergent themes were added as analysis progressed and comprised: stage (planning, design, procurement, etc.), definition of GSCMC, use of theory and stakeholders. Analysis proceeded by coding theme: a brief summary was produced for each theme. The summaries were then integrated into an initial synthesis which drew out the main themes, gaps and areas for future research. This overview was then checked back to the papers in a second, detailed review. The thematic summaries were extended, the overview findings were refined and the future agenda was expanded into greater depth to provide the final synthesis. A limited set of themes from analysis and from the synthesis are presented below due to restrictions on space.

## ANALYSIS

### Research interest over time

No qualifying papers were found from before the year 2000. A small proportion (16%) were published up to and including 2011 and the field shows an increase in interest from 2012 and a more dramatic upturn in 2016 and 2017 (see Fig. 1). With growth in interest in GSCM in general being mapped to the early 1990s (Zhu and Sarkis, 2006), it would appear that construction and allied research fields have been slow to adopt the concept but that research interest in application of the concept is now firmly underway.

*Fig 1 Number of papers by year of publication*



Note: papers published up to 31.08.2017 were reviewed so the 2017 total is partial.

### Source journals

The 44 papers appeared in a surprisingly large variety of journals, 31 in total, with only three publications including multiple papers on the topic: Journal of Cleaner Production published 10 of the papers; Sustainability (Switzerland) published three, and Journal of Construction Engineering and Management, and WIT Transactions on

Ecology and Environment, each published two. With papers published in disciplinary outlets ranging from Waste Management to Resource Policy to Building Research and Information, there is evidence of wide interest in GSCMC and related topics, with recognition of its importance across many disciplines. The range of publication outlets also speaks to the multi-faceted nature of the construct.

## Methods

A variety of methods has been used to examine different facets of GSCMC (see Table 2). Fifteen papers applied specialised quantitative methods, including material flow analysis, modelling, lifecycle analysis (LCA) and organisational environmental footprint, to examine particular questions within the GSCMC process. The remainder of the studies used a range of methods: interviews only (5), survey only (6), mixed methods of interviews and surveys (5) and case studies (6). In most cases, the number of cases was appropriate for detailed analysis, with up to 31 individual professionals being interviewed, and usable responses on surveys ranging between 39 and 455. The literature therefore is generally founded on a solid empirical base. The exceptions were studies with low numbers of interviewees (2), and one paper in which data sources were not quantified making it difficult to assess robustness.

*Table 2 Methods used in reviewed papers*

Method	Number of papers	Further information
Interviews	5	n = 4 to 31
Surveys	6	n = 39 to 455
Mixed	5	Interviews n = 6 to 29; surveys n = 27 to 84
Case study	6	Cases included reuse process; project supply chain
Action research	1	
Lifecycle analysis	7	Lifecycle analysis and associated methods
Other modelling	8	Including decision models for subcontractor selection
Commentary or literature review	6	

## Stakeholders

The range of stakeholders referred to in the papers surveyed illustrated the complexity of the construction supply chain. Beyond the suppliers and logistics operators who would be expected to feature in SCM more generally, reference was made to developers and clients (10 papers), construction professionals including architect/designers, engineers, project managers and specialist subcontractors (15), and principal contractors (4). Opinions varied on the level of commitment and motivation of different stakeholder roles. While most authors who commented on stakeholder responsibility considered the client/developer as an important driver, not all considered the general contractor to be motivated to green the supply chain (Wong et al., 2016). Some scholars viewed designers as having limited incentive to collaborate in green supply chains (Wong et al., 2016, Balasubramanian and Shukla, 2017b) but others argued that the design team has a major influence on the final

product through design and materials selection (Albino and Berardi, 2012, Arroyo et al., 2016, Sertyesilisik, 2016).

The absence of discussion of stakeholders in almost one third of the papers, however, represents a weakness in the literature reviewed, through omission of one of the primary foci of GSCM (Ahi and Searcy, 2013). Further, as Balasubramanian and Shukla (2017b, 2017a) argued, stakeholder perspectives differ and therefore the different standpoints, approaches and objectives of each stakeholder should be examined.

### **Definitions of GSCMC**

Not all authors sought to define GSCMC. Many of the papers with a complementary focus to GSCMC defined ancillary concepts such as lean or sustainable construction, sustainable materials management, waste management and reverse logistics. Where authors provided definitions of GSCMC, most were operationally focused, specifying the constituent processes. Green procurement featured extensively, along with green manufacturing, green distribution, green purchasing, green production, green consumption, green transportation, green design, packaging and waste minimisation. These processes themselves were rarely defined. The objectives of GSCMC were considered in some papers, and these were proposed to be: to enhance competitiveness, to add value for stakeholders, to improve environmental, economic and operational performance, to improve service, increase market share and sustainability of supply, to increase operational efficiency, cut costs and minimise risks or for ethical reasons, and to reduce environmental impact. Surprisingly few authors attempted to consider a more conceptual perspective although in a small number of papers, there was recognition of the holistic, end-to-end perspective. These papers emphasised integration of processes between suppliers and clients and integration of green practices into business processes and into inter-organisational SCM. The findings here echo those of Ahi and Searcy's (2013) systematic review of GSCM definitions, in which they found limited consideration of principles of business sustainability such as a stakeholder focus and long-term perspective.

### **Theory**

Given that GSCMC is a form of SCM (Ahi & Searcy, 2013), an a priori assumption that the research papers would draw extensively on SCM work to inform their studies theoretically was not borne out. Use of the SCM literature was generally limited although a few papers harnessed previous insights from SCM, including an end-to-end perspective and the importance of trust to facilitate inter-firm integration, issues of supply chain integration and the importance of co-makership in innovation. The absence of theoretical frameworks for GSCMC was a noticeable weakness in the literature surveyed, with a few exceptions. Balasubramanian and colleagues offered the only new theoretical framework proposed for GSCMC in the papers reviewed (Balasubramanian, 2014, Balasubramanian and Shukla, 2017a). Deriving first a quadrant-based categorisation of enablers of GSCMC, based on an extensive review of the GSCMC literature (Balasubramanian 2014), Balasubramanian and Shukla (2017a) proposed and tested a nine-construct structural model, in which they demonstrated the relationship between internal and external drivers and barriers to core and facilitating green practices, and the relationship between core and facilitating green practices and environmental, economic and organisational performance. Further, they tested these relationships for four main roles in construction (developer/client; architect/designer; major contractor; material suppliers). This

represents an important step forward in the literature in offering a tested framework which future research can seek to apply or extend.

## **SYNTHESIS**

### **Overview**

The review of 44 papers showed rapidly increasing interest in topics associated with GSCMC, following somewhat later than a more general surge in research interest in GSCM in other industries (Zhu & Sarkis 2006). The spread of journals in which relevant studies have been published demonstrates wide interest and is a promising basis for a thriving research domain. A mixture of methods has been used, including in-depth interviews, surveys, mixed methods, case studies and modelling, which provides a generally robust empirical base, with a few exceptions where insufficient data were provided.

### **Definition**

A point of note was the failure of many papers to define explicitly what they understood by GSCMC. Da Rocha and Sattler (2009) drew on earlier definitions of SCM as (a) the activities involved in the flow of goods or services from primary source to end client and (b) the integration of the main processes between suppliers and end client to add value for stakeholders. The latter usefully draws attention to a strategic business objective of SCM – that of adding value – although the definition is quite narrow in its limitation to integrated processes: this omits critical aspects of SCM such as developing inter-organisational relationships. The former definition, in contrast, uses a broad conceptualisation but the underlying model is linear which poses problems for a sustainable economy in which circularity – the retrieval and reuse of resources - must feature.

Across the set of papers, it is noteworthy that there is limited discussion of how GSCMC may be understood as similar to but differentiated from SCM. A final striking absence in terms of definition is the concept of ‘true sustainability’ – the notion that the end goal (even if not wholly achievable) must be the absence of adverse environmental impact, the potential for positive environmental contribution and for indefinite continuance of the supply chain (assuming non-supply chain factors remain favourable) (Pagell and Wu, 2009). Drawing on the papers reviewed, a definition of GSCMC is now offered.

GSCMC comprises the management of all activities in an organisation related to minimising the environmental impact of all of its supply chains which contribute to its final products, with the aim of achieving zero net harm and the potential to operate indefinitely, given an available market. The activities comprise, at a minimum, green purchasing. GSCMC can also include green design, green manufacturing, green transportation, waste management, green operation and end-of-life management. The objectives of GSCMC comprise improved environmental performance, improved business performance through greater efficiency, increased competitiveness and increased value to stakeholders. Across all supply chain actors, GSCMC requires management of the above activities to achieve the required objectives, that is, planning, control, measurement, monitoring and evaluation. The activities, objectives and management of GSCMC will vary by role of firm, as discussed below. Successful GSCMC requires relationship management as part of greater integration of business processes and systems along supply chains.

This is offered as an overarching definition and is therefore relatively abstract, aiming to address the notion of GSCMC at a conceptual level. There remains a need for complementary and partial definitions at a more concrete level, relating directly to perspective of stakeholders.

### **Stakeholder perspective**

Within construction, critically, the role of the firm influences its primary GSCMC activities, with the contractor holding key responsibility for green transportation, and architectural and engineering consultants for green design, for example. This entails fundamentally different processes and different management challenges. By implication, different definitions of GSCMC by stakeholder may be appropriate. Balasubramanian and Shukla (2017a) have led the way in their analysis by organisation type but further research specific to the role in the construction project team is needed.

## **FUTURE RESEARCH AGENDA**

Having synthesised key themes from the papers, gaps which merit further research were identified.

### **Detailed research on subdomains**

The complexity of supply chains in construction speaks to the need for both detailed, subdomain specific as well as sector generic research. For example, it is not known if the same principles or the same priorities in operational processes and procedures apply across all types of projects – are there differences, for example, in managing the supply chains for residential development where high numbers of units of similar design will be constructed, and in managing the supply chains for a mixed-use commercial development? Similarly, it is not yet known if the same approach should be taken for different components and materials. Studies to add to knowledge are required which consider the issues by size of focal organisation, by material (further work on timber and aggregate, new studies on window systems, roof systems, HVAC, for example) and by type of project (in addition to the work on residential, studies on commercial, health, education, hospitality, and infrastructure projects).

### **End-to-end perspective**

Further, an holistic, end-to-end perspective is also needed – a long-term view which in practical terms should look for the greatest impacts along the supply chain in order to achieve the greatest and/or most rapid improvement. Although it has been suggested that the failings of any one link in the supply chain weakens the supply chain's overall performance (Balasubramanian & Shukla, 2017a), not all supply chain roles are equal. Supply firms may vary dramatically with respect to their environmental impact, and resources (time, expertise, finance) are best applied to the most damaging aspects in the chain. This points to the value of a 'hotspot' analysis along a whole supply chain (Dadhich et al., 2015) to facilitate the most effective commitment of resources and potentially quicker beneficial impact.

### **Stakeholder perspective**

In parallel with an end-to-end perspective, potentially owned by the client, there is a need to investigate further what GSCMC means for different roles within the supply chain. Building on the work of Balasubramanian & Shukla (2017a), research is needed on the similarities and differences of managing a green supply in developers, primary and general contractors, tier 2 contractors, specialist subcontractors, trades, different

types of consultancy, and process (e.g. cement) and product-oriented (e.g. façade systems) suppliers.

### **Particular challenges of construction**

The ARCOM2018 theme of balancing fragmentation and integration highlights a primary area for future research within GSCMC. Of the reviewed papers, the few which gave thorough consideration to the nature of the construction sector pointed to challenges to the industry. The project-based nature of construction which contrasts with long-term alliances in manufacturing, for example, means that relationships between commissioning firms and suppliers are often one-off and short-term, and are often characterised as adversarial (Ofori, 2000). This works against the SCM ideal of deepening relationships with suppliers to pursue integration of processes (Seuring and Gold, 2013). In particular, the development of trust between firms, identified as crucial to stronger inter-organisational relationships (Loorbach et al. 2010), takes time to develop. Within construction, it has been noted that partnering and alliances do not necessarily bring trust and absence of competition (Bossink, 2007). Although alluded to, the issues of fragmentation and the challenges of integration along construction supply chains have not yet been subject to detailed study.

Beyond these gaps, more critical perspectives have yet to be considered (e.g. Gold & Schleper, 2017). These topics warrant research scrutiny if the potential of GSCMC to address the socially critical concerns of environmental impact is to be realised.

### **REFERENCES**

- Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. *Journal of cleaner production*, 52, 329-341.
- Albino, V., & Berardi, U. (2012). Green buildings and organizational changes in Italian case studies. *Business strategy and the environment*, 21, 387-400.
- Arroyo, P., Tommelein, I. D., & Ballard, G. (2016). Selecting globally sustainable materials: A case study. *Journal of construction engineering and management*, 142(2), 05015015.
- Balasubramanian, S. (2014). A structural analysis of green supply chain management enablers in the UAE construction sector. *International journal of logistics systems and management*, 19(2), 131-150.
- Balasubramanian, S., & Shukla, V. (2017a). Green supply chain management: an empirical investigation on the construction sector. *Supply chain management*, 22(1), 58-81.
- Balasubramanian, S., & Shukla, V. (2017b). Green supply chain management: the case of the construction sector in the United Arab Emirates (UAE). *Production planning and control*, 28(14), 1116-1138.
- Banawi, A., & Bilec, M. M. (2014). A framework to improve construction processes: Integrating lean, green and six sigma. *International Journal of Construction Management*, 14(1), 45-55.
- Bossink, B. A. G. (2007). The interorganizational innovation processes of sustainable building: A Dutch case of joint building innovation in sustainability. *Building and environment*, 42(12), 4086-4092.

- Briner, R. B., & Denyer, D. (2012). Systematic review and evidence synthesis as a practice and scholarship tool. In D. M. Rousseau (Ed.), *The Oxford handbook of evidence-based management*. Oxford: Oxford University Press.
- Dadhich, P., Genovese, A., Kumar, N., & Acquaye, A. (2015). Developing sustainable supply chains in the UK construction industry: A case study. *International Journal of Production Economics*, 164, 271-284.
- EU. (2015). Construction and demolition waste (CDW). Retrieved 16.3.2018, from <http://bit.ly/1ERule1>
- European Commission (2008). Raw materials initiative - meeting our critical needs for growth and jobs in Europe. COM(2008) 699. Brussels: European Commission
- Gold, S. & Schleper M.C. (2017) A pathway towards true sustainability: a recognition foundation of sustainable supply chain management. *European Management Journal*. 35:425-429
- Gough, D., Oliver, S., & Thomas, J. (2012). *An introduction to systematic reviews*. London: Sage.
- Kibert, C. J., Sendzimir, J., & Guy, B. (2000). Construction ecology and metabolism: Natural system analogues for a sustainable built environment. *Construction management and economics*, 18(8), 903-916.
- Loorbach, D., van Bakel, J. C., Whiteman, G., & Rotmans, J. (2010). Business strategies for transitions towards sustainable systems. *Business strategy and the environment*, 19(2), 133-146.
- Lucon, O., Urge-Vorsatz, A., Zain Ahmed, H., Akbari, P., Bertoldi, L. F. & al. (2014). Buildings. In *Climate Change 2014: Mitigation of Climate Change*. Cambridge: Intergovernmental Panel on Climate Change.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The Prisma Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med*, 6(7), e1000097.
- Ofori, G. (2000). Greening the construction supply chain in Singapore. *European Journal of Purchasing and Supply Management*, 6(3), 195-206.
- Pagell, M., & Wu, Z. (2009). Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. *Journal of supply chain management*, 45(2), 37-56.
- Sertyesilisik, B. (2016). Embending [sic] Sustainability Dynamics in the Lean Construction SCM. *YBL Journal of built environment*, 4(1), 60-78.
- Seuring, S., & Gold, S. (2013). Sustainability management beyond corporate boundaries. *Journal of cleaner production*, 56, 1-6.
- Wong, J., Chan, J., & Wadu, M. (2016). Facilitating effective green procurement in construction projects. *Journal of cleaner production*, 135, 859-871.
- Zhu, Q., & Sarkis, J. (2006). An inter-sectoral comparison of green supply chain management in China. *Journal of cleaner production*, 14(5), 472-486.