Current Practices and Insights on Supply Chain Risk Management in the Construction Industry: A Review

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Abstract: This paper reviews the related studies on the current practices and insights in supply chain risk management within the construction industry. Articles published between 2000 and 2018 are classified and analyzed using simplified systematic literature review, which is performed through the material collection, category selection and literature matrix. While the research on supply chain risk management started relatively recently, much of these studies were generic and not contextualized for the construction industry. Construction supply chains risk treatment and monitoring phase require further attention, with inputs from all the supply chain actors in the upstream linkage. Only peer-reviewed journal articles were considered in this study. And it is hoped that the findings will serve as a guide to construction managers who would like to better understand how risks in the upstream and downstream linkages of construction supply chains are managed. We acknowledged that the implementation of construction supply chain risk management is immature, and there is a dearth of literature in this area. This study also identifies the risk management process currently practised in the industry and provides a framework for literature classification. The study identifies literature gaps that can provide opportunities for future research in the area of CSCRM. It also discusses future research directions in this area.

Keywords— *Supply Chain Management, Risk Management, Construction Industry, Malaysia.*

1. Introduction

The fragmentation and adversarial nature of the construction industry have been widely agreed by the industrial practitioners and academics as the main reason for poor performance and slow improvement in construction projects. There have been global calls for improved collaboration, integration, communication and coordination between the clients and the suppliers in construction projects since the end of the 1990s to improve the efficiency of the construction supply chain (CSC) [1], [2], [3], [4], [5], [6]. However, the research on the integration of CSC since the 1980s up to 2010s has been scattered and partial [2]. Although the manufacturing industry, as well as other sectors, such as retail distribution, have recorded outstanding improvement towards integrated supply chains, the construction industry is yet to duly integrate its supply chains such that the concept of construction supply chain management (CSCM) has become a hard nut to crack in practice [7].

The CSC is not a single flow 'chain' but a network of multiple organisations and relationships involving the flow of funds, materials, labour, information, plant, equipment and temporary works; and the integration of CSC is a part of the CSCM [8], [2]. The problems related to CSC are found to have the possibility of generating significant disruption to projects [8], while the problems in CSC are often stemmed from the lack of visibility on the CSC. As identified by [2], the top five risk factors in CSC risk management include the inadequate communication, late involvement of the parts, lack of concurrent design, inadequate selection of suppliers and inadequate IT system. For instance, the public organisation

strategy in Malaysia to outsource construction projects allows flexibility for the organisation, but it also hindered the sharing of information and data among the project team members [9]. In several instances, the partnering in CSC often focus only on clients and the main contractors, the clients in most cases were reluctant to engage with subcontractors and suppliers [7]. Therefore, it is often down to the decision of main-contractor to maintain the relationships and trust with the suppliers and manufacturers.

The traditional CSC structure as suggested by [10] is divided into upstream linkage and downstream linkage, wherein the upstream linkage involves the clients, designer and consultants with work related to the preparation of the production on-site; and the downstream is the linkages involving the main-contractor, sub-contractor, suppliers and manufacturers with works related to the execution of tasks in the project delivery. But, the competitive tendering process in the construction delivery often results in adversarial contract relationship, with pricing remained the primary criterion in contractor appointment; whether it is between client and main contractor, or between main-contractor and sub-contractor; trust between whichever parties involved is almost inexistence [11].

It should be noted that the construction industry is mostly dominated by small-medium enterprises (SME) firms in the downstream of the supply chains, but the material suppliers and the manufacturer are often not included in the main construction contract [12]. From the green building development perspective provided by [13], the lag in the CSC's response to green building development creates a bottleneck for green initiatives. Although the clients, designers and main-contractors are well-versed and committed to green building development projects, those in the downstream of the supply chain are lacking in the knowledge and remained sceptical on the returns of such investment directions. Since it is not clear of who will reap the benefits of improving the relationship of the CSC, the downstream stakeholders are not motivated in improving it [14]. As such, [7] proposed a need for the clients and the main contractors to embrace the downstream players in the CSC for a successful implementation of CSCM.

Studies on construction supply chain risk management (CSCRM) is mostly underpinned by CSCM and risk management. Unsurprisingly, there is a dearth of literature on CSCRM given the fact that the CSCM is yet to mature. Thus, the focus of this review is to address the current practices and suggest future trends on the CSCRM.

2. Research Methodology/Literature Classification and Selection

This study utilizes a simplified systematic literature review, which is performed through the material collection, category selection and lastly literature matrix. The literature search was performed with the Emerald Insights and the Taylor and Francis Online through the Swinburne University of Technology Sarawak's (SUTS) library. The search was restricted to peer-reviewed journal articles to enhance the quality of the search results. The keywords chosen for the search include 'supply chain management', 'construction supply chain', 'construction supply chain management', 'supply chain risk', 'supply chain risk management', 'supply chain integration' and 'construction supply chain risk management'. The articles for the past 18 years are considered sufficient to cover the latest knowledge, updates and future trends in the field of CSCRM.

Table 1. Criteria for material collection.

	Inclusion	**Exclusion**
Material source	Databases: Emerald Insights; Taylor and Francis Online through the Swinburne University of Technology Sarawak's (SUTS) library subscriptions.	Non-academic and unreliable data sources.
Material type	Published academic papers from peer-reviewed journals.	Working paper, standards and professional guidelines.
Publication period	From 2000 to 2018	Out of the period
Keywords (SCM, CSC, SCR, SCRM, SC integration, CSCM, CSCRM)	Articles mention, describe and analyse the keywords' content.	Articles only mention the keywords, little to no mention of 'construction' or 'supply chain'

A total of 42 articles were gathered to perform the categorisation. The articles regarding construction risk management from [15] was excluded considering its irrelevance to the domain of supply chain. Similarly, articles regarding supply chain management without a particular emphasis on construction (such as [16], [17], [18] were also removed during this categorisation. As indicated in Table 2, only the articles that have both 'construction' and 'supply chain' in their context are selected for further review. Considering the fact that construction supply chain management is broad in scope, the categories were further broken down into related sub-focus to properly assign and find the most relevant articles. Further removal from the list during the classification is the study on CSCM organisation planning and typology by [19], [20] and the study on CSCM productivity by [21]. The rationale behind their removal was the lack of direct focus on supply chain risk management. Hence, 35 papers were retained for review based on their relevance to the current trends in the construction supply chain management. Out of these 35 articles, the seven articles that addressed the CSCRM specifically are studied in-depth as indicated in Table 3 which summarised the themes, findings, and implications of the seven selected articles.

Table 2. Literature Classification.

The core focus of the literature	**Sub-focus**	**Literatures**
Construction Supply Chain Management (CSCM)	Supply Chain Integration	Dainty, Millett & Briscoe (2001); Cox & Ireland (2002); Love, Irani & Edwards (2004); Briscoe & Dainty (2005); Zou, McGeorge & Ng (2005); Albaloushi & Skitmore (2008); Bankvall *et al.*, (2010); Segerstedt & Olofsson (2010); Khalfan & Maqsood (2012); Das, Cheng & Law (2015); Broft, Badi & Pryke (2016) [11], [22], [1], [7], [12], [23], [24], [25], [26], [27], [28]
	Relationship	Green, Fernie & Weller (2005); Davis (2008); Pala *et al.*, (2014); Kim & Nguyen (2018) [29], [30], [31], [32]
	Supplier Selection	Chen *et al.*, (2018); Seth *et al.*, (2018) [33], [34]
	Review	Behera, Mohanty & Prakash (2015) [35]
	Planning	Thunberg, Rudberg & Karrbom Gustavsson (2017); Thunberg & Fredriksson 2018 [36], [37]
	Logistics	Vidalakis, Tookey & Sommerville (2011) [38]
	Lean	Erik Eriksson (2010) [39]
	Change Management	Fernie & Thorpe (2007) [40]
	Awareness	Arantes, Ferreira & Costa (2015) [41]
	Claims Management	Stamatiou *et al.*, (2018) [42]
Construction Supply Chain Risk Management (CSCRM)		Hatmoko & Scott (2010); Aloini *et al.*, (2012); Panova & Hilletofth (2018); Rudolf & Spinler (2018); Zainal Abidin & Ingirige (2018); Le *et al.*, (2018) [8], [2], [43], [44], [9], [45]
Construction Supply Chain Risk Management (Green Perspective)		Zou & Couani (2012) [13]
Construction Supply Chain Management (Green Perspective)		Balasubramanian & Shukla (2017a); Balasubramanian & Shukla (2017b); Balasubramanian & Shukla (2018) [46], [47], [48]

Table 3 - Summary of the Themes, Findings, and Implications of the Selected Articles.

Author and Date	Theme	Methodology	Findings	Implications for future research and practice
Hatmoko & Scott (2010) [8]	To produce a simulation model that measures the impact and test the performance sensitivity of the project to alternative SCM practice.	Survey questionnaires formed through preliminary investigations. Simulation model utilises Pertmaster Risk Expert software.	Suggested that problems related to the construction supply chain are likely to generate significant disruptions. The study quantifies the benefits of using subcontractors to reduce the risk of delay and reinforced the view that such an arrangement can improve project performance.	Provided a platform for future investigations on the impact of supply chain delays.
Aloini *et al.*, (2012) [2]	To develop an operative framework that can identify the risk factors that affects the success of the SCM approach adoption in the construction industry.	Systematic literature review. Critically select and classified about 140 research articles according to a risk management perspective.	There is a lack of construction supply chain risk management (CSCRM) literature. The related CSCRM literature is at the infancy of study, hence remain conceptual, descriptive and only focus on the risk assessment phase. The authors identified 13 common risk factors for the construction supply chain and confirm the main contractor as the main promoter of the SCM practice.	Review the state of the art in the field of CSCRM. Therefore, the study provides direction for developing the next phases of the risk management framework. Suggested that empirical case studies should be conducted to investigate and test the developed model.
(Zou & Couani 2012) [13]	To develop strategies that manage the major risks in green building development through the understanding of the major risk and their distribution in the supply chain.	Collect responses from supply chain members through a questionnaire survey.	The risk in the green building supply chain is unequally distributed throughout the supply chain member, with the contractor bearing the most risks across the network. Suggests improvements to green building project through research and development, supply chain coordination, knowledge and information sharing, and technology application.	The author claimed that the paper is the first study in identifying the supply chain risk in green building development.
Le *et al.*, (2018) [45]	To understand the present focus of CSCM and identify the future trends of CSCM.	Systematic literature review.	The present CSCM application is still focusing on internal supply chain integration. The early phase of planning and design often did not conduct the CSC risk identification. The future of CSCM is heading towards the	Provides a summarization on the current CSCM and the future proposals for CSCM implementation and improvement.

			integration of Lean, BIM and advanced planning and design techniques with CSCM.	
Panova & Hilletofth (2018) [43]	To identify the model combination that is suitable for assessing and mitigating risks regarding time and cost of delays in the construction project.	The study considered the different risk assessment methods and reviewed the literature to determine risk factors and approaches. Empirically validate the findings from literature through visual simulation modelling utilise AnyLogic and Vensim computer packages.	Dynamic simulation is suitable for portraying the dynamic nature of the delays in the delivery of the material to the construction site and its probability to disrupt the CSC. Monte Carlo method is less effective due to its vague representation of time. Propose to increase safety stock of construction materials to mitigate risks in the CSC.	Suggest the contractor find their right level of safety stock for their project instead of leaning their site storage through Just-in-time delivery because such an arrangement increases the risk of stock out considering the untimely delivery of material.
Rudolf & Spinler (2018) [44]	To make the SCRM more applicable to large scale engineering, procurement and construction (EPC) project through contextualising SCRM by identifying the supply chain risk portfolio specific to large scale EPC project.	Identified and categorised the key supply chain risks through a systematic review of recent literature. Surveyed the project managers for large scale EPC project across multiple industries.	The risk portfolio for large-scale construction project deviates from the risk portfolio for a generic construction project. The risks are considerably underestimated at the project beginning due to various biases. The often-ignored behavioural risk is identified as crucial to the large-scale EPC project.	Provide standardise risk classes and factors to perform supply chain risk assessment of large-scale EPC project more efficiently. Suggesting further study on the large scale SCRM through an in-depth case study within a single project.
Zainal Abidin & Ingirige (2018) [9]	To formulate the resilience level of construction projects in handling disruptive events through assessment of supply chain's perceptions on their vulnerabilities and capabilities.	Collect response from both public and private organisations that work in public projects through a questionnaire survey. Analysed and compared the data from the survey using Mann-Whitney U and Kruskal-Wallis tests.	Public organisations faced higher political threats compared to the private organisation, but the private organisation faced higher market pressure instead. The financial vulnerability in the public organisation can destabilise the entire supply chain despite the private organisations having the high financial capability. The outsourcing strategy of the public organisation increase its flexibility but had also reduced its visibility over the supply chain operations.	Provides a new perspective to observe the dynamics of the cascading impacts of supply chain vulnerabilities through several layers of supply chain members. Suggested the use of information technology (IT) tools such as Building Information Modelling (BIM) to improve the transparency of supply chain information as well as building better relationships with key players in the CSC.

3. Result and Discussion

CSCM and CSCRM Papers Published in Peer-Reviewed Journals.

Between 2010 and 2018, there were only 7 journals that published CSCRM-related papers, where each journal contributed one CSCRM article. Within the period under consideration, there were at least 14 peer-reviewed journals that published papers regarding construction supply chain management (CSCM). The 'Supply Chain Management: An International Journal' contributed nine CSCM papers and one CSCRM paper, followed by the 'International Journal of Construction Management' which contributed four CSCM papers and one CSCRM paper. As indicated in Table 4, the ratio of papers between CSCM and CSCRM is 5:1. The actual difference is expected to be more if a bigger sample of paper selection is considered for this review.

The mention of 'risk' in the CSCM literature before 2010 has only referred to the generic risk management in the construction projects, and the literature focuses more on the supply chain integration. [44] confirmed that the application of generic risk management in a large-scale construction project is high while the supply chain risk management is applied only to a lesser extent. This is because the research on the supply chain risk management started relatively recently, and the risk management for the supply chain was generic and not contextualized for the construction industry [2], [44].

In terms of methodology, questionnaire and interview are the most common research methods adopted by most researchers working on the CSCRM, followed by the systematic literature review. Simulation and modelling are expected only when there is sufficient study on the topic to support the data inputs required for such method [49].

Table 4 - Peer-reviewed journals on CSCM and CSCRM (2000 to 2018).

Journal Title	No. of CSCM papers	No. of CSCRM papers
Architectural Engineering and Design Management	0	1
Built Environment Project and Asset Management	1	0
Business Process Management Journal	0	1
Construction Innovation	2	1
Construction Management and Economics	2	1
Engineering, Construction and Architectural Management	6	0
Industrial Management & Data Systems	2	1
International Journal of Construction Management	4	1
International Journal of Logistics Research and Applications	1	0
International Journal of Managing Projects in Business	1	0
International Journal of Physical Distribution & Logistics Management	1	0
International Journal of Production Research	2	0
Production Planning & Control	4	0
Supply Chain Management: An International Journal	9	1
Total	**35**	**7**

3.1 Result and Discussion

The selected papers originated from twelve countries, with the United Kingdom contributing significantly to the research of CSCM but with only one paper addressed the supply chain risk in construction specifically. This is followed by Australia in CSCM research, and one paper on CSCRM. Despite the high contribution in CSCM research from Sweden and USA, no paper addressed supply chain risk in the construction industry from the researchers in these two countries

based on the selected papers for this review. Instead, the study on CSCRM is scattered in seven different countries (except the USA and Sweden) with each country contributed only one paper.

Table 5 - Countries and the number of CSCM and CSCRM articles published

Country of origin	No of CSCM articles published	No of CSCRM articles published
United Kingdom (UK)	12	1
Australia	4	1
Sweden	5	0
United States of America (USA)	2	0
Canada, Germany, Italy, Russia, Indonesia	0	1 each (total 5)
India, Portugal, Qatar	1 each (total 3)	0

3.2 Current Practices of Construction Supply Chain Risk Management

Risk originated from CSC, such as materials delay, labour shortage, information loss, plant and equipment breakdown can disrupt the project, and result in delay and cost overruns. In most cases, the main contractors bear the most risk across the CSC, they, however, have the most strategic position to manage all the project stakeholders and the resources along the supply chain, because of their roles as the key project coordinator [8]. Subcontracting is a common strategy adopted by main contractors to transfer their risk in the project, the trend of reducing directly employed labour has created many 'hollowed-out' construction firms that retain only managerial and administrative staff [29]. The risk avoidance strategy through out-sourcing did not prevent the construction projects from failing, instead, it worsened the fragmentation in the industry.

The study of [2] indicated that the construction industry has recognized the importance of the CSC to project success, unfortunately, studies on CSC risk mostly focused on the risk assessment phase, while the subsequent treatment and monitoring phase usually receive less attention. The identification of CSC risks required inputs from all members in the supply chain, not just the triad of the client, designers and main contractor, from the upstream linkage. However, the implementation of CSCM has mostly stayed at the level of internal integration, where common goals are easier to align and focus only on material and resources management within the organisation [45]. It is only recently that [44] provides more standardised risk factors and classes to make the risk assessments more efficient, but it is still essential to involve all supply chain members to understand the dynamics in the CSC network. Previous studies have also proven that a company needs to interact with its neighbouring companies to carry out business, as their processes and activities are always interrelated [28].

The construction industry has realized that the current SCRM adopted from the manufacturing industry becomes less applicable as the scale of the construction project increase and agree that there is a need to modify the SCRM process to reflect the specific requirement of construction projects [44]. As early as the 2000s, the researchers in CSCM have been focusing on the integration, partnerships, trust and relationship buildings of the CSCM. But the focus has slowly shifted towards the developments and study on the in-depth frameworks to solve the managerial problems of CSCs. Besides, the integration of the downstream linkage into the CSCM has gained more attention because it is a precondition to the efficient use of many information technology tools [45].

4. Future trends of construction supply chain risk management

Although the evolution of CSCM has been slower than the general trend in SCM, the CSCM continues to evolve with the advancement of information technology. Since the 2010s, more researchers have paid attention to the integration of lean [39]; Building Information Modelling [50]; and logistics [38]; to the CSC to improve the efficiency of construction projects [45]. The horizontal organisation structures proposed by [51] is to improve the collaboration and communication and minimise the barriers to information flow in projects. This horizontal organisation structure is similar to the structure proposed for a construction project delivery using BIM protocol [52]. In this instance, the responsibility for project development

is shared and the contractors, suppliers and manufacturers are religiously engaged right from the planning and design phase. Notably, the involvement of the key suppliers and subcontractors in planning and design can decrease the risk of non-compliance. Even though the horizontal organisation structures suppose each organisation implements a form of the quality management process, the collaboration increases the productivity by ensuring correct information and expectation are communicated between the clients, the contractors and the suppliers [1].

The Building Information Modelling is widely believed to be able to facilitate knowledge sharing for construction project and is strongly recommended as a data source for the CSC members to create, share and use the data together [53], [54], [55], [56], [45]. The readiness of 3D modelling allows the expansion of the model into nD modelling to include data regarding the time sequencing, the cost, and possibly the supply chain logistics and location. Such expansion into nD modelling aims at integrating additional design and construction aspects with BIM-based 3D models to enhance the lifecycle analysis of a building project [57] (Fu, Kaya and Kagioglou G. Aouad 2007). The contractor may outsource the management of their logistics activities, such as transportation, material procurement and storage, to logistics professionals if the firm is lacking the expertise. Furthermore, the suggestion for integrating Lean in CSCM is argued to have a negative effect on the supply chain instead of enhancing the process flow and eliminate wastes and errors [43]. This is because the Just-In-Time concept in Lean principle favours the idea of the complete elimination of buffer stock but also stripped off the capacity of the contractor to respond to adverse events. The integration of the CSCM, BIM and Lean is just conceptually proposed with no study on the practical implementation found, hence these areas are under-researched.

5. Concluding Remarks - Some Suggestions for Future Research

While several established researchers have made several contributions to the literature over the last decade, this study has also highlighted new opportunities for future research on construction supply chain risk management especially with regards to areas such as lean construction, building information modelling (BIM), logistics and improving the efficiency of construction projects. The common practice and assumption from the literature about risk avoidance are through out-sourcing/subcontracting by the main contractor - an obduracy that has worsened the construction industry fragmentation in the project delivery over the years. The calls for the integration of CSC is hard to realise due to the complexity of CSC network, whereas the introduction of information technology tools is seen as a way forward to solving the persisted communication difficulty in the CSC.

Despite the progress of the CSC literature in ad-hoc empirical papers, most authors express their concern about the lack of influence of the CSC on other important constructs in the built environment, such as green building development; and the extent to which such constructs can be used as predictors of commitment to the principle of sustainable construction (as indicated in [58]. There is a need to pursue further interests and exploration of more holistic theoretical frameworks to clarify the imbalance and the fragmentations in conceptualizing CSC. Similarly, more conceptual and empirical multi-disciplinary studies on supply chain risk management in the construction industry are required to both practitioners in the upstream and the downstream linkages.

One of the limitations of this study lies in the relatively small category of articles selected and reviewed as compared to a formal systematic literature review. This makes this study based solely on the analyses from the viewpoint of academics. Only articles from peer-reviewed journals were considered with the exclusion of inputs from the industrial practitioners. Therefore, the views of practitioners on CSCRM are not incorporated. The limitation on the database access and the time constraint imposed on this study does not allow a wider collection of articles. Inherently, the classification and categorization for the CSCM remained broad and could be further breakdown into more detailed categories.

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