BUILDING RESILIENT SUPPLY CHAINS FOR CONSTRUCTION SMALL AND MEDIUM SIZED ENTERPRISES

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Along with global economic growth and the prevalence of global trade, uncertain and turbulent markets can lead to construction supply chain vulnerabilities and disruptions. Within this environment, small and medium enterprises (SMEs) in the construction industry are booming, despite being considered one of the most vulnerable sectors in the economy. Therefore, construction SMEs need to implement fundamental changes and adopt agile methods of coping with supply chain uncertainties to withstand the effects of unpredicted events, such as the COVID-19 crisis. In Australia, SMEs account for more than 99% of all Australian enterprises and deliver up to 60% of the total value of the construction industry. This research aims to identify resilience factors to optimize the supply chains of the SMEs in construction industry. Through a systematic review of literature, this research firstly identifies the resilience factors under the general supply chain environment. Subsequently, it systematically identifies the resilience factors for construction supply chains and SMEs supply chains with an objective to characterise the similarities and difference in these factors. Finally, this research demonstrates and applied these resilience factors in a small Australian building company. This research will contribute to the body of literature of resilient supply chains and to qualitative and quantitative research into building of resilient supply chains in the construction sector SMEs.

Keywords: supply chain; globalization; resilience factors; resilient supply chain; SME

INTRODUCTION

External risks or disruptions in local branches may not be considered as a severe impact for a large global organization. However, these risks can be significant if they strike small and medium sized enterprises (SMEs). Since SMEs only have less than 250 employees and account for 70% of the global production, supply chain disruptions can severely affect the sustainability of SMEs (Bak *et al.,* 2020). According to Wedawatta (2010a), the construction SMEs were the least prepared business sector compared to manufacturing, retail, transportation, or business and financial services. After conducting an extensive literature review on the supply chain resilience, Bhamara *et al.,* (2011) called for researchers to conduct empirical studies specifically for SMEs.

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The aim of this study is to identify supply chain resilience factors for construction SMEs to enable these companies to manage potential risks. This will be accomplished by identifying resilience factors in the supply chain literature and comparing these to the factors that apply to the construction supply chain given that construction is often characterised as 'project-based' and not dependent on enduring supply relationships. The next step was to examine how these resilience factors apply differently to construction SMEs. Examples of these resilience factors from an Australian home builder's perspective are listed.

LITERATURE REVIEW

Along with the disruptive events happening around the world, researchers have focused on improving supply chain resilience (SCR) to reduce and prevent the potential supply chain risks (Christopher and Peck 2004). This study will adopt the definition for SCR proposed by Christopher and Peck (2004) and Ponomarov and Holcomb (2009): "capability of a supply chain to develop required level of readiness, response and recovery capability to manage disruptions risks, get back to the original state or even a better state after disruptions."

Supply chain resilience

In an extensive review of supply chain management literature, Chowdhury and Quaddus (2016) identified the antecedent factors for SCR through structural equation modelling and analysis. Following on their 2016 study, Chowdhury and Quaddus (2017) affirmed that SCR is a multidimensional and hierarchical model, which consists of three primary dimensions, including proactive and reactive capabilities, and supply chain design quality. They further established that SCR to incorporate factors of operational vulnerabilities (OV) and supply chain performance (SCP). Moreover, Chowdhury *et al.,* (2019) developed the SCR model by considering external context variables, supply chain relational practices (SCRP) and network complexities (NC) and proved the link between SCRE and supply chain performance was strengthened through the interaction effect of SCRP and NC. Therefore, the supply chain network complexities were conceptualized based on Chowdhury and Quaddus (2017).

The most comprehensive supply chain resilience conceptualised network was developed by Chowdhury and Quaddus (2017) is structured with four major classifications of factors as shown in Table 1.

Table 1: Supply chain resilience factor model (Adapted from: Chowdhury and Quaddus 2017:196)

Proactive Factors	Reactive Factors	Design Factors	Operational Vulnerability Factors
(i) Disaster readiness	(i) Response	(i) Node density	(i) Skilled workers
(ii) Flexibility	(ii) Recovery	(ii) Complexity	(ii) Production/inventory management
(iii) Reserve capacity		(iii) Criticality	(iii) Utility supply
(iv) Information integration			(iv) Product quality
(v) Efficiency			(v) Worker supervision
(vi) Market strength			
(vii) Financial strength			

Construction supply chains

Although construction supply chain management (SCM) is closely related to the general SCM methodology, Vrijhoef and Koskela (2000) identified four distinctive roles in construction including focusing on the interface between supply chain and construction site, focusing on supply chain, focusing on transferring activities from construction site to supply chain, and focusing on the integrated management of supply chain and construction site. Due to the external risks and construction project complexity, the construction SCM is a unique and problematic issue in the construction industry (Wang *et al.,* 2017). Efficient construction supply chain management can improve the project performance and reduce the potential material waste. Construction supply chains have complex networks which require a comprehensive project management plan, strict budgetary controls, and effective monitoring of the construction schedule. These additional complexities increase the SCM risks and difficulties (O'Brien *et al.,* 2008).

A systematic literature review was conducted using the Scopus search engine for construction supply chain resilience (SCR) using the following search string:

"<TITLE-ABS-KEY (construction AND supply AND chain AND resilience) AND (EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "PHAR") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "PSYC")) AND (EXCLUDE (DOCTYPE , "ch")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English")) >".

A total of 35 articles were obtained and after filtering through all these articles for relevance, accessibility, duplication, and completeness, only 17 articles were selected. These articles are marked as [CONS] in the list of references.

SME supply chains

While SMEs are essential for economic growth and innovation, a supply chain disruption can have disproportionate repercussions for SMEs compared to larger firms. SMEs face two main challenges: their susceptibility to disruptions and their ability to recover from disruptions. In comparison with large firms, SMEs often lack sufficient resources, technological systems, financial abilities, and enterprise management systems, and are therefore viewed as more vulnerable (Sullivan-Taylor and Branicki 2011). Also, SMEs must adopt new innovative capabilities to cope with the challenges brought on by globalization. Hence, it is important for SMEs to constantly update and modify their management strategies to fulfil their customers' needs and to stop them leaving for their competitors.

Based on the literature review carried out by Arthur-Aidoo *et al.,* (2015), the Bolton Committee first formulated both "economic" and "statistical" definitions for small firms in 1971. From the "economic" perspective, there are three criteria. Firstly, they have a relatively small share of their marketplace. Secondly, they are managed by owners or part owners in a personalized way instead of a formalized management structure. Thirdly, they are independent and not recognised as a large enterprise branch. As for the "statistical" definition, the three criteria include the revenues of the firm, contribution to value add, and the number of employees. The Bolton Committee's definition for small firms in manufacturing, construction and mining industries was based on the number of employees, namely 200 or fewer employees while the European Union defined SMEs as firms that employ less than 250 persons and have annual turnovers not exceeding EUR 50 million.

According to the Australian Bureau of Statistics (ABS), there were more than 2.3 million SMEs in Australia in 2017-18. SMEs account for 99.8% of all enterprises in Australia. According to Gilfillan (2018), small businesses have 71.1% of the total employment in the construction industry and contributed 59% of the construction Industry Value Added (IVA). Based on Australian Taxation Office (ATO) guidelines, a business with an aggregated annual turnover of less than AUD 10 million from 1st July 2016 is identified as a small business. The ABS adopts a different definition for SMEs based on the number of persons employed (Gilfillan 2015): (i) 0-4 persons belong to a micro business; (ii) 5-19 persons belong to a small business; (iii) 20-199 persons belong to a medium business; (iv) 200 or more persons belong to a large business.

The next search for SMEs was carried out using this search string:

"<TITLE-ABS-KEY (supply AND chain AND resilience AND for AND smes) AND (EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "ECON") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "ENER")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re"))>".

A total of 18 articles were obtained and after a similar filtering process, only 9 articles were selected and marked as [SME] in the list of references. Only two articles, Wedawatta *et al.,* (2010a) and Wedawatta *et al.,* (2010b) were associated with SMEs in construction industry and were concerned with the impact of extreme weather events.

RESULTS

A compilation of general supply chain resilience factors from Chowdhury and Quaddus (2017) is presented in the first column of Table 2. These factors are further elaborated for applications to the construction industry in the second column, and additionally for SME firms in the third column. The literature clearly shows that several additional factors were evident for the construction sector and for SMEs compared to the general SCR. These include reduced financial capacity and resources, unclear organisational structure, tendency to overlook industry norms and regulations, and a lack of risks management tools.

DISCUSSION

Resilience factors in the construction sector and those specifically pertaining to construction SMEs were mapped and compared to the general supply chain resilience factors. While the construction and SME sectors have factors that are analogous to the general supply chain resilience, they also exhibit several additional factors that were exclusive to either construction or SMEs.

Construction supply chain resilience

In contrast with general supply chain resilience, construction companies are exposed to different disruptive events during various project phases together with potential changes in regulations, policies, material standards during the project's life cycle. Project sites are exposed to poor weather conditions, site hazards, and other environmental hazards with site resilience being defined as "anticipation" by Vrijhoef and Koskela (2000). Construction supply chain needs additional "adaptability" features to ensure project can be finished within the anticipated time, and "capacity" factors for alternative suppliers, backup equipment and repair agreements. In addition, the construction enterprises should build up reflective business models to

keep upgrading the business operations to comply with the business goals. Information integration shall apply to the entirety of construction project stages to minimise the potential risks caused by misunderstanding. In construction "efficiency" denotes managing the construction process and avoiding variations. Additionally, the construction sector must manage different transportation nodes, and project stakeholders need to build a strong network and maintain a positive relationship.

As for the "reactive" factors, construction companies should have knowledgeable leaders to manage the whole project team and develop protocols and procedures to comply with the construction legislations. Considerations about quality, cost and time when selecting suppliers and subcontractors, prepare risk mitigation strategies, and improving project team communication are additional factors for the construction sector. In contrast to the general supply chains, construction supply chains have numerous stakeholders (including users, client, designer, contractor, subcontractors, and suppliers) to be considered in the whole supply chain design process. From an "operational vulnerability" perspective, construction supply chains are susceptible to skills shortages or turnover since it takes a long time for a skilled or professional worker to attain competency in the industry. The industry also needs to maintain a high level of safety for works at the construction site.

Table 2: Supply chain resilience factors from construction and SME perspectives

Column 1 Supply chain resilience factors	Column 2 Application to construction industry	Column 3 Application to SMEs	Column 4 Examples from an Australian SME
Proactive Factors (i) supply chain disaster readiness: readiness training, research, warning signals, forecasting, security	Involve contractors in pre-disaster planning: immediate relief, long term recovery. Disaster management: developing and implementing disaster planning; preparedness strategies. Additional: Anticipate extreme weather events: forecasting possible delays, employ experienced professionals to plan and forecast, regular maintenance, adequate safety training, manage custom clearance process, quality control, hire skilled labour. Time dependence: disruptive events have a dissimilar impact at various times after the initial event. Situational awareness: the enterprise has comprehensive understanding of project risks, such as construction site hazards, environmental/natural hazards, failure of lifelines etc. Political or regulatory changes: Building code update and material standard update.	Supply chain disaster readiness: improving resilience to EWEs. Additional: Logistic resilience: production plan, warehouse information, documented procedures, Insurance for transportation Personnel training Risk taking External situation monitoring and reporting. A safety management system	List all relevant information before the project starts. Consider unpredictable events before project started. Prepare project schedule. Purchase shipping insurance for materials from overseas. Assign tasks to relevant personnel. Develop site safety management plan. Consider about extreme weather events during project planning stage. Keep update the latest regulations and standard.
(ii) Flexibility: ability to produce a wide variety of product based on customer requirements, flexibility in contract with supply chain partners, flexibility of sourcing, distribution	Flexibility: alternative transportation routes, alternative supply sources, vertical integration, flexible supply agreements. Additional: Adaptability: early orders, adequate buffer time in between supply chain and onsite, well planned site layout, well planning material loading/unloading, enhanced site supervision, frequent maintenance.	Flexibility: offer products more often and more innovatively. Have a faster response in the process.	Predict the potential risks based on experience. Update the management methods/communicatio n methods based on the current situation. Plan project schedule as early as possible to avoid material shortage and project delay.
(iii) Reserve capacity: backup machinery, equipment, logistical options, and energy source	Capacity: have alternative transportation backups, supplier backups, alternative machine/equipment backups, emergency repair agreements, machinery instead of labour, specialised sub-contractor. Additional: Reflective business model: Companies regular self-evaluation and assessment to update the business operations in terms of their goals.	Capacity: offer a broader range of products, ability to adjust demand capacity, Delivery and inventory, capability and capacity of internal resources.	Prepare for contingency plans or have alternative suppliers. Establish material order lead-times, material delivery period and subcontractor booking period. Build up business model to conduct self-assessment and improve business operation efficiency.

(iv) SC information integration	Visibility: advanced IT systems, RFID tags to track prefab units	Information integration: purchasing Information technologies	Updated records of material purchase information/project progress and share information to other project stakeholders
(v) Efficiency: waste reduction, quality control, productive employees	Efficiency: automated manufacturing, avoiding variation. Additional: Transportation nodes	Efficiency: demand forecast in the logistic area	Ensure that materials can be delivered on time by contacting the suppliers/subcontractors a few months earlier before the project starts.
(vi) Market strength: buyer/supplier satisfaction, supplier product differentiation	Market position: have healthy, long-term relationship with client; market pressure; sensitive to market; robustness of network	Market strength: customer service, social network relationships, higher customer-oriented performance Additional: Improvements: improvements to quality	Update the clients/owners with the latest information and obtain feedback. Provide professional advice to the client. Communicate with the client and solve problems positively.
(vii) Financial strength: diversified business portfolio, fund availability	Financial strength: adequate contingencies, insurance coverage, healthy cash flow	Financial strength: sufficient cash flow	Ensure sufficient funding is available based on the contract. Conduct precise estimating before sign the contract to make sure company has sufficient cash flow.
Reactive factors (i) Response: quick response, adequate response team	Additional: Leadership and management: the company has experienced leaders with a wise vision of its objects. Aligned business practice: the organisation implements protocols and procedures that are compliant with legislation. Primary performance: product quality, commodity price and cost, delivery and service	Response: Internal situation monitoring and reporting, emergency response. Additional Indicators to measure performance. Innovativeness.	Communicate immediately to seek solutions. Post-completion review and list improvements for future projects.
(ii) Recovery: quick recovery, reduction of impact and reduction of recovery cost	Recovery: have professional team deal with vulnerabilities, consequence mitigation strategies, improve project team effective communication		Record the past project problems and make project risks mitigation plan.
Supply Chain Design Factors (i) Node density: concentrated market vs diversified market	Additional: Supplier/subcontractor: competitive supplier selection; procurement process	Additional: Production plan.	Build a database of suppliers. More than two subcontractors/suppliers each type of work.
(ii) Complexity: more tiers, multiple buyers	Contractor: collaboration; dispersion - empower site staff control the process quality		Actively communicate with project stakeholders.
(iii) Criticality: alternatives for critical supply/item	Designer/Owner: sustainability for design and environment; eco-design; energy resilience		Fully review the working drawing before construction to collaborate with architects.
Operational vulnerability factors (i) Skilled workers	Efficiency: improve labour productivity. Additional: Difficulty in finding the right people	Difficulty in finding the right people	Retain good employees.
(ii) Production/inventory management	Material inventory management	Inventory policies	Conduct construction management plan to sufficient manage materials on site or on stock.
(iii) Utility supply disruption	Utility supply disruption	Utility supply disruption	Install temporary utilities and facilities before work starts
(iv) Product quality	Quality management Additional: Sensor technology	Quality management	Experienced site manager
(v) Worker supervision	Security: onsite safety	Onsite safety management	Experienced safety manager

Construction SMEs' supply chain resilience and future research opportunities

Construction SMEs are particularly concerned with extreme weather events since the supply chain and project sites can be adversely affected. SMEs need to focus on logistic resilience, personnel training, and using risk control method to continuously

monitor the external situation and update their database to prevent potential risks. Despite their limited size, SME contractors are obliged to develop a safety management system.

As for the "flexibility" factor, construction SMEs are more likely to be client oriented, therefore, they need to update their product or services in an innovative way and response to the project stakeholders efficiently. The project management team needs to collaborate with the clients, and to manage project schedule in an efficient way to avoid material shortage issue and project delays.

Regarding "capacity", "information integration" and "efficiency" factors, SMEs are more related to construction relationship network and management process. Construction SMEs must ensure that they have sufficient capacity to cope with supply chain disruptions. The whole SME supply chain network needs to collaboratively build up business resilience to maximize the use of resources and suppliers based on different construction SMEs' organizational goals, therefore, improve the supply chain efficiency (Sahebjamnia *et al.,* 2015). Further research also needs to consider how to build up information integration system for construction SMEs as these SMEs do not adopt advanced technologies such as BIM (Hosseini *et al.,* 2016).

In the "market and financial strength" dimension, SMEs should continuously improve their construction or product finish quality to satisfy the clients' requirements. They also need to maintain a positive communication system with clients. The SMEs always require sufficient funds to ensure the company can run smoothly. While SMEs contributed 60% to the Australian economy, SMEs are consistently facing financial constraints. Therefore, policy makers should enact policy initiatives to strengthen SMEs' financial position and their contribution to the economy (Banerjee 2014).

As for "reactive" factors, construction SMEs should develop their own indicators to evaluate their project performance after the project is completed, and apply lessons learned to improve their future project quality. In addition, SMEs should also innovate their construction scheduling and management system to keep up with the current practices.

For the "supply chain design" and "operational vulnerability" factors, construction SMEs need to positively build up their own project stakeholder database. In addition, since there is no clear organizational structure, employees normally handle multiple tasks in construction SMEs, therefore, it is hard for SMEs to find a right person to replace the original staff.

This review has revealed several gaps in construction SMEs' resilience factors that can be addressed in future research projects. These include developing qualitative methods to identify additional risks in construction together with quantitative methods such as structural equation modelling to prioritise these risks (Wang *et al.,* 2014). Other research areas include evaluating innovative organisational structures for construction SMEs (Davis *et al.,* 2016), the investigation into level of collaboration with SMEs' key project stakeholders (Bak *et al.,* 2020), identifying the response (internal and external) and recovery strategies, improving leadership roles to maintain a positive relationship of all the project stakeholders and maintain good employees and managers (Gallego-Roquelaure 2020).

CONCLUSION

This systematic literature review on the resilience factors for both construction and SMEs supply chains aims to improve supply chain resilience by compiling, adopting,

and linking all applicable supply chain resilience factors. The review has clearly identified factors that are common between supply chains in general, construction supply chains, SMEs, and construction SMEs. More importantly, the review has identified factors that specifically pertain to construction and construction SMEs that will be the subject of future research into construction SCR. The review has also confirmed the limited research into the resilience of construction SMEs in the light of recent disruptions. This will adopt either in-depth interviews, quantitative data analysis or case studies on construction SMEs to expose and elucidate further resilience features.

This review contributes to the body of knowledge concerning construction supply chain resilience, also demonstrates the supply chain resilience factors for construction industry and particularly focused on construction SMEs. This research is expected to form the basis for further qualitative and quantitative research in supply chain resilience for construction SMEs in the light of increasingly challenging global trade tensions and supply disruptions as the result of the pandemic.

Some limitations of this paper include the review of only the Scopus database and the application of SMEs supply chain resilience factors solely from an Australian perspective. Future research may be extended to examine resilience from other project stakeholders' perspective.

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