Resilient Supply Chains in Industrialised Construction: A Hong Kong Case Study

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ABSTRACT

A recent report from the McKinsey Global Institute, suggests seven areas that can boost the construction sector productivity including improved Supply Chain (SC) and onsite execution to overcome the remarkably poor productivity of the construction industry. Although Industrialised Construction (IC) as an appealing approach has been perceived to improve the productivity of the construction, the fragmented nature of prefabricated SCs nurture variety of vulnerabilities on IC in Hong Kong (HK), and these disruptions beset the industrial performance. Hence, 'Supply Chain Resilience (SCR)' has attracted the emerging interest of academic researchers and industry practitioners which enable proactive disruption management that transcends conventional wisdom and standard practices. This research, therefore, aims to explore the level of vulnerability of IC SCs to the disruptions and proposes a set of counteractive capabilities a firm should develop to withstand these vulnerabilities based on a case study in HK. Data was collected through unstructured interviews with six professionals of the selected case, document reviewing, frequent site visits, and analysed using N-Vivo based content analysis. Thus, the main thrust of this study is to propose strategies to enhance SCR in IC in HK to enhance the productivity of IC through value enhanced SCs.

Keywords: Supply Chain Resilience (SCR); Industrialised Construction (IC); Vulnerabilities; Capabilities

INTRODUCTION

There is a significant knowledge gap in the strategies and measures for capitalising on the drivers for productivity enhancement in the construction industry in Hong Kong (HK) (Construction Industry Council, 2019). Therefore, it is suggested to go for offsite construction as one of the key solutions to sustain Hong Kong's economic growth through the enhanced construction industry's productivity and competitiveness. Also, a recent report from the McKinsey Global Institute, suggests seven areas to boost construction performance, including improving onsite execution and its supply chain. Under these circumstances, Industrialised Construction (IC) is appealed in the HK construction industry by demarcating its superiority over the traditional construction practices (Li et al., 2018). Increased use of off-site manufacturing furthers the industrialisation of the construction process (Rwamamara, 2007) and the intensity and the nature of production activities are changing with the industrialisation since it facilitates cost-effective methods and more efficient methods such as off-site prefabrication and on-site assembly. However, potential benefits may not be fully exploited if inherent weaknesses of IC supply chains including fragmentation, discontinuity, and poor interoperability not being mitigated, which nurtures a variety of risks that impose significant adverse influence on the performance of IC (Li et al., 2018). Although conventional risk management has appeared as a strategy to address these issues, it is evident that it cannot adequately address all the supply chain disruptions (Van Der Vegt et al., 2015), hence calling for a new focus on disruption management that transcends conventional wisdom towards standard practices (Ekanayake et al., 2019). In this context, the concept of 'Supply Chain Resilience (SCR)' has recently attracted the emerging interest of industry practitioners and academic researchers.

However, there is a dearth of literature on achieving resilient supply chains in the construction industry (Zainal and Ingirige, 2018) and no known research for IC. As there is a vital need to fill this lacuna, this study aims to explore the level of vulnerability of IC supply chains to the disruptions and propose a set of counteractive capabilities a firm should develop to withstand these vulnerabilities in a preliminary framework for IC in HK.

LITERATURE REVIEW

The concept of SCR is broader than mitigating risks (Ekanayake et al., 2019) and enables organisational capacities to deal with disruptions effectively (Fiksel, 2015). Hence, SCR is 'the ability of a supply chain to react proactively to disturbances and to return to its original state or a more desirable one' (Ponomarov and Holcomb, 2009). It is onerous to apply traditional risk management strategies to every possible disruption (Pettit et al., 2010) and these strategies are inadequate to provide the required protection against the disruptions which are triggered by uncertainties whose root causes are unrevealed (Van Der Vegt et al., 2015).

Besides, achieving resilient supply chains is vital in IC since IC supply chains are complex due to (i) a longer chain caused by two production environments, namely, factory and site; (ii) larger amounts of design work and earlier design for cast-in-situ construction because of the prefabrication lead time; (iii) longer error correction period; and (iv) higher requirements for dimensional accuracy. In the IC supply chain, there are three main phases, namely prefabrication factory, logistics, and the on-site assembly (Zhai et al., 2015). Uncertainties of the construction arising from the processes involved in these supply chain phases include machine breakdown, lack of materials in the producing process, traffic jams and low efficiency of customs clearance in the shipping process, and component damages during transportation and assembly. These uncertainties pave the path for time and cost overrun in the construction projects (Zhai et al., 2015). Also, these complex supply chains involve continual turbulence, creating a potential for unpredictable disruptions. Therefore, supply chain disruptions can be identified as the major threats to the organizations. Effective management of those disruptions will be critical for ensuring timely project delivery in IC (Li et al., 2018).

Under these circumstances, many researchers tend to understand the value of the concept of SCR where resilience imperatives call for supply chains to be less brittle and more adaptive to change through supply chain design, enhanced capabilities across the supply chain, visibility to demand and supply throughout the supply chain, supplier and customer relationship management and finally infusing a culture of resilience (Murphy, 2006). According to Pettit et al. (2013), SCR is derived from an appropriate balance between the associated vulnerabilities and capabilities in the supply chains. Supply Chain Vulnerabilities (SCV) are the key disruptions that disturb the typical construction process and are unanticipated and unplanned (Zavala et al., 2019). These vulnerabilities can be counterbalanced by implementing appropriate managerial controls through Supply Chain Capabilities (SCC): 'attributes that enable an enterprise to anticipate and overcome disruptions' (Pettit et al., 2013). Therefore, several researchers conducted studies on SCV and SCC and suggested several approaches that could be followed to enhance SCR. As explicated above, although achieving resilient supply chains are vital to IC in HK, there is no known attempt by researchers to explore the subject matter. Therefore, this study fills the long-neglected gap of research by probing, then proposing 63 strategies to achieve resilient supply chains in IC in HK. The forthcoming sections of this paper describe the research methodology followed in this study, report the findings, explicate the SCV in IC in HK and propose SCC as the strategies to enhance SCR in IC in HK, and finally, derive the conclusions with a recommended way forward.

RESEARCH METHODOLOGY

This paper presents an important piece of research work of an ongoing Ph.D. study which aims to develop an evaluation model to enhance SCR in IC in HK. Besides, this study targets to propose strategies to enhance SCR in IC in HK to improve the productivity of IC through value enhanced SCs, based on a preliminary case study in HK. The purpose of conducting a case study is to secure theoretical generalization rather than statistical generalization. Therefore, only a small number of cases are usually recruited for in-depth analysis (Fellows and Liu, 2015). In order to guarantee theoretical generalization of the case study, a public housing construction in HK was selected, which is considered to be representative of IC in HK for the following reasons; (I) this project is developed by the largest IC client in HK providing public housing for over 50% of its residents, (II) the contractor is a reputed, top graded and well experienced contractor in the field of IC sector in HK and having project teams with similar management skills as other IC project teams have, and (III) all the public housing projects are very similar except for site conditions, with the floor plan, structure type, assembly cycle, and volume and types of precast components being the same for each of a few standard designs. This justifies the generalisation from the case study project.

All the required data from the selected case was collected through unstructured interviews with six project professionals of the selected case, document reviewing and conducting frequent site visits to the chosen case. All the interviewees were top managerial level industry experts who involved in the selected case and, they were with more than 10 years' experience in the IC industry in HK as well. Each interview was conducted as a face to face interview at the construction site office and continued for 1-2 hours. Table 1 presents the details of the interviewees [Note: interviewee statements will be cited hereafter, followed by [R1] or [R1, R2] or [R1-R3] to convey that these were by R1, or both R1 and R2 or from R1 to R3]. Further, all the necessary information for the study were gathered until the data saturation was reached. The research approach adhered is appropriate for this study since qualitative research methods are representing the views, experiences, believes, and attitudes of a specific set of people and it is ideal for research on emerging conceptions through in-depth investigations (Yin, 2017).

Table 1. Profile of the Interviewees

Interviewee	Experience	Position
R1	12 years	Assistant project manager
R2	10 years	Site Engineer
R3	15 years	Project Manager
R4	12 years	Quantity Surveyor
R5	10 years	Site Engineer
R6	18 years	Site Engineer

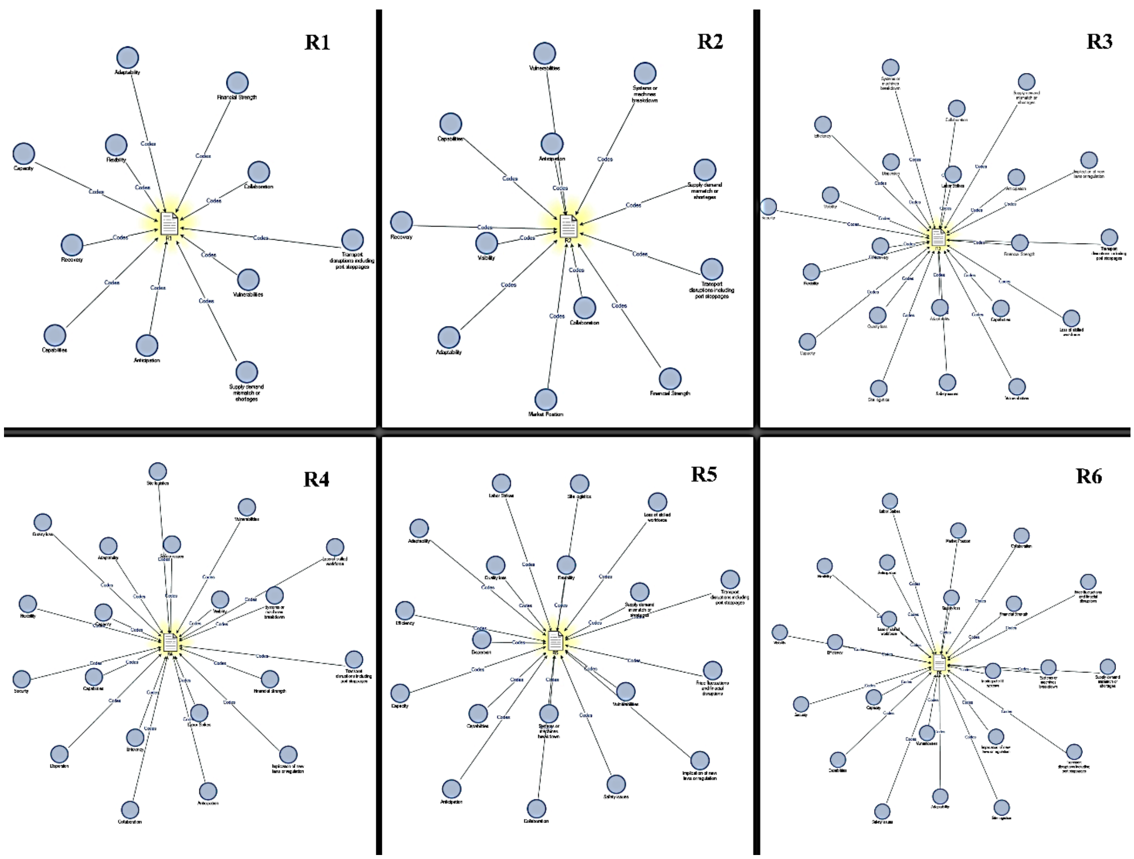

Figure 1. Explore diagrams of the interviewees

In HK, most of the public housing construction projects are IC projects since they value the benefits associated with IC over the traditional construction methods. Although, investigating several cases would be more meaningful in revealing the existing situation of IC in HK, time constraints and information privacy in the construction industry make it very difficult to obtain more data from several projects. Therefore, this selected representative case study project provided valuable insights regarding the actual situation of SCR in IC in HK at the initial stage of this research. This selected case is running from 2018 to 2020, with the aim of constructing 36 storied residential tower block with 1020 units, including one basement (car park, plant room), 4 stories including podium for commercial shop, car park, landscape area, plant room, podium garden, and multi-function room.

Gathered data from this case study were then analysed using code-based content analysis with the use of N-Vivo12 software. Figure 1 depicts the 'explore diagrams' developed using N-Vivo12 software and highlights how these interviewees contributed to the gathered data and how the data saturation was reached (These explore diagrams map the respondents' statements with the relevant nodes that they are linked). Thereby, this study generated its key findings by proposing strategies to enhance SCR in IC in HK. Further, the case study findings provided empirical justifications to the current practice of IC in HK. However, the ongoing Ph.D. research study will further administer a mixed method approach in collecting data which includes subject matter expert surveys and several case studies to develop a model and validate the findings for the HK construction industry. Since this paper is based on the preliminary results of this Ph.D. study, it may be seen to lack of dense empirical validation of the results. However, these essential preliminary findings lay a firm foundation for the next stage of this research study.

RESEARCH FINDINGS AND DISCUSSION

During the interviews, all the project experts stated that this project was subject to many supply chain vulnerabilities and there is a dire need for counteracting strategies that could be called 'supply chain capabilities' to withstand these disruptions. As said by R5, "IC supply chains work well if we planned well from the beginning, according to my understanding. Otherwise, we will end up with huge losses". Therefore, it is required in IC in HK to find ways to enhance their project performance by the improved supply chain performance as targeted from the SCR.

Supply Chain Vulnerabilities (SCV)

"There must be many vulnerabilities in a project supply chain, and we as a team have to forecast project programme to check whether these uncertainties can be solved before the project commenced" [R1, R2, R4]. Further, "they claim money, time and affect the project completion in the short term and the long term" [R1, R2]. "IC supply chains are mostly affected by transport disruptions. These are due to port stoppages, traffic jams, customs clearance issues, and damages to the units in transporting" [R1-R6]. Also, "IC supply chains affect by technical problems with vehicles, too late or too early delivery, and insufficient transportation capacity" [R6]. "Some fittings come from Europe to our site. So, it will take a longer transportation time. Once there was a delay and, the logistic company took 3 months for delivery. So, we need to place orders earlier" [R1, R2]. "Sometimes, we had to order very long segments, oversized pre-fabricated units. They could not transport easily to HK site via roads. The buses were around, and it was very difficult at that place. Therefore, the same size segments should arrive in batches and can transport at night. And need to store another site nearby until site operations start" [R5]. "Transportation vulnerabilities are higher in our site. Because many of our materials come from Mainland of China. And we hold the material at the custom for customs clearance. Maybe one- or two-days delay is expected from that" [R2]. Further, "at the customs clearance at the customer department, we have much inspection and documentation. So, we face problems and delays there. Even they return the components which are with poor documentation. We face these disruptions many times" [R3, R4]. Therefore, all the respondents identified the transportation disruptions as the major vulnerability that they face in IC.

In addition, "HK sites are not so large. So, before transfer the components to the site we need to store outside, we call it horizontal transportation and lifting to the location we call it as vertical transportation. These are the site logistics, and finally, we install. In these 4 major fields, we feel many disruptions" [R3]. As R3-R6 identified, site logistics is allied with many vulnerabilities in IC in HK due to the inadequate space for storage because most of the sites are congested. "So, this is our priority to consider. And the second, during the construction period, site logistics is very busy, we must handle so many components at the same time. There are some components/vehicles waiting outside to enter the site for a long time or several hours. Even a few days sometimes. Because we have many construction materials dealing in the same day or same time. So, they queue outside" [R3, R4]. "Factory tells us that they are ready, and they can send the segments to us, but unfortunately, we are not ready to accommodate them since there is no space or room. Sometimes although stored, the cranes cannot reach the place due to poor onsite logistics, which cause problems and a challenge" [R5]. Therefore, "site logistics should be planned in advance during design stage" [R6].

It was very prevalent to see the machine breakdowns, especially the tower crane breakdowns, which caused delays [R2-R6]. "Breakdown of the tower crane makes the construction process out of operation more than one to two hours until maintenance company repairs it" [R2]. As per R3, machine/equipment breakdown is possible at the manufacturing factory since they deploy outdated machines with low efficiency. Apart from the tower crane, the material hoist is also susceptible to the breakdowns. "Material hoist's breakdown is also common, and this break down our overall vertical transportation route" [R4]. "Disruptions at the manufacturing factory causes supply-demand mismatch in IC [R3], and it is quite serious here [R5]". "These include shortage of materials, labor inefficiency, internal supervision problems, and machine/equipment breakdown" [R3]. "Sometimes, when we need segment type 1, the factory sends us the type 2" [R5]. "Delaying prefab items cause very negative impacts on our projects, and we need to be careful in selecting the suppliers. Based on the previous project records, we go for the same suppliers. But, if they were repeating the mistakes, we may find another. Generally, we face delays at least once a month" [R6]. However, the accumulated supply-demand mismatch ends up in unmet client needs.

"Although the accidents are seldom in IC in HK, if an accident happens, the impact will be severe because we have high-risk operations" [R1]. However, "we have faced several accidents in this project. Fortunately, no one got seriously injured" [R3].

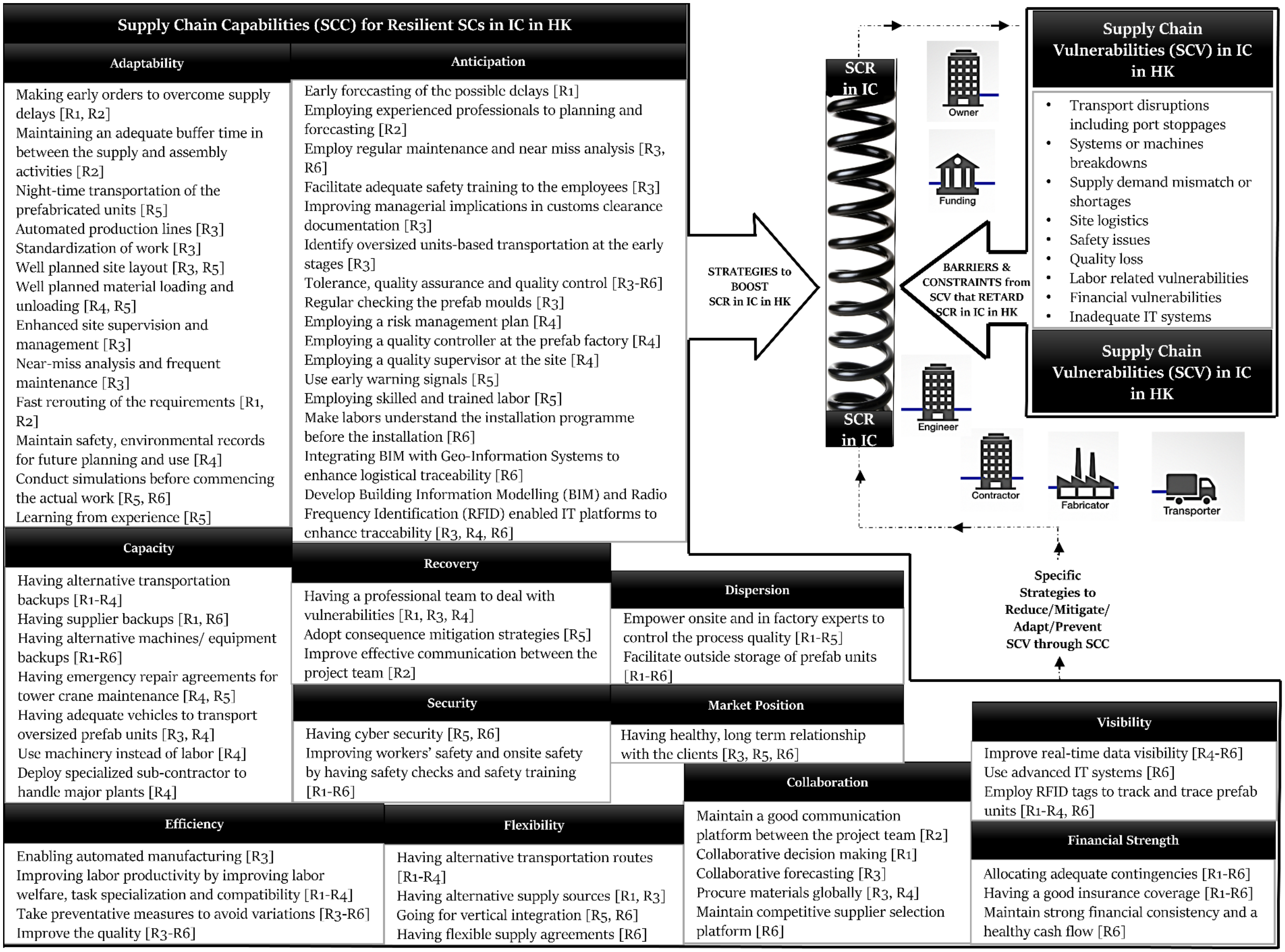

Figure 2. Strategies to achieve resilient supply chains in IC in HK

According to the respondents, most of these accidents were due to lifting operation failures, heavy lifting, untidy, and uncomfortable working environment, installation accidents, and unloading the precast elements. In addition, "a lot of near misses are common, including dropping the segments, small tools, and small equipment" [R5]. Although IC targets a safe working environment, these accidents and near misses may cause severe hazards if necessary precautions are not taken.

Quality control matters since prefabricated units are manufactured from China [R5]. "Mostly, they are tolerance issues in IC. If one unit is cast with 1mm error, the process becomes vulnerable to assembly problems which cause cost, time overrun" [R6]. Loss of skilled workforce and labor strikes affect the productivity of IC significantly. "Shortage of labor, unskilled labor, less skilled labor, some strikes, and the continuous rising of labor cost (last two years it was around 30% of rising) affect the construction efficiency" [R4]. According to R6, inadequate IT systems, information losses, and inadequate information exchange also cause many vulnerabilities in the project supply chain.

Supply Chain Capabilities (SCC) as Strategies to Enhance SCR

As explicated above, there is a dire need for 'counteractive' capabilities to withstand these vulnerabilities (Ekanayake et al., 2019). Hence, Figure 2: a framework consisting of 63 strategies to achieve resilient supply chains in IC in HK was developed according to the case study findings of this study. All the suggested capabilities were categorized under the key SCC constructs developed by Ekanayake et al., (2019) namely Flexibility, Capacity, Efficiency, Visibility, Adaptability, Anticipation, Recovery, Dispersion, Collaboration, Market Position, Security and Financial Strength.

As conveyed by the interviewees, the HK construction industry practises most of these strategies to achieve resilient supply chains in IC. However, there should be a specific level of adopting each strategy according to the project requirements. For instance, although maintaining an adequate buffer time in between assembly and the order of materials, "too early orders cause site-logistic issues in the storage of the prefabricated units because HK sites are very small" [R3, R4]. In addition, in these projects, contractors appoint a professional quality checker to the prefab factory to overcome tolerance issues. Also, they have currently deployed a Building Information Modelling (BIM) enabled Radio Frequency Identification (RFID) system to enhance real-time data visibility and traceability of the prefabricated units as a new initiative. Although, it is vital to accommodate other strategies as appropriate to successfully withstand all those key vulnerabilities, including safety issues, transportation disruptions, labor, and site logistic based disruptions.

CONCLUSION AND A WAY FORWARD

Findings presented in this paper determines the SCV that trigger the key disruptions to IC supply chains in HK and counteractive SCC, which could help to withstand these SCV. In this respect, a framework including 63 strategies to achieve resilient supply chains in IC in HK was prudently developed by consolidating and generalising the appropriate case study findings using N-Vivo based content analysis. Figure 3 depicts these study findings, including SCC and SCV, in IC in HK in a word cloud format, which is developed via N-Vivo based content analysis of the case study data.

The preliminary framework developed in this study would be vital to the industry stakeholders not only in identifying associated SCV but also for formulating and/or nurturing adequate SCC measures to realise resilient supply chains in IC in HK. This preliminary framework will be further explored in the next phase of the current research study through strong empirical justifications and case study validations to formulate an evaluation model to enhance SCR in IC in HK. The study outcome would lead to the improved project performance and productivity in IC in HK through value enhanced supply chains in IC.

Figure 3. Word cloud on resilient supply chains in IC in HK

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