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Impact of COVID-19 on the China-Australia Construction Supply Chain

Chigozie Victor Ndukwe[1*], Jinyun Liu[2], Toong Khuan Chan[3]

Abstract: The Australian construction industry has historically imported building materials from Europe, US and Japan but more recently seen dramatic increases in imports from Asia. The construction industry is heavily reliant on imports of building materials such as steel, windows, joinery, tiles, float glass and curtain walls from its top trading partner, China. The supply of these building materials was disrupted amid the confusion in response to the initial spread of the COVID virus in China leading to widespread lockdowns and the temporary closure of manufacturing plants. By March 2020, the virus has spread by infected international travelers across the globe bringing numerous cases into Australia. This study aims to examine the impact of COVID on the supply of building materials from China to Australia specifically focusing on the state of Victoria. The objectives of this study are to map out the risks that have crystalised on the China-Australia construction supply chain; examine the impact of upstream disruption in China on downstream activities; and assess how the timing of local pandemic outbreak impacts supply chain performance. Using procurement data from a residential builder, we observed disruption of production, delay, increase of shipping costs and loss from foreign exchange. The delay was up to two weeks due to the shutdown of manufacturing plants in China during the early stages of the pandemic. When the first wave of infections spread into Australia, its impact on the building and construction industry was minimal. The greater impact occurred when limits were placed on site workers during second wave of infections which desynchronised the Australian and Chinese sides of the supply chain. The builder experienced additional two-weeks delay on small scale residential projects and four-weeks delay on a large-scale residential project. These findings may assist the industry to find ways to manage future risk of disruptions to their supply chains.

Keywords: Australia, Building products, COVID, Risks, Supply Chain Performance.

[1*] Chigozie Victor Ndukwe
Corresponding author, Faculty of Architecture Building and Planning, University of Melbourne, Australia
E-mail: cndukwe@student.unimelb.edu.au

[2] Jinyun Liu
Topgan Construction Pty Ltd., Australia

[3] Toong Khuan Chan
Faculty of Architecture Building and Planning, University of Melbourne, Australia

1 Introduction

Supply Chain (SC) risks arise from different sources and can be categorised into operational and disruption risks (Kleindorfer and Saad, 2005; Tomlin, 2006; Sawik, 2011; Fahimnia, et al., 2018). There have been previous attempts in studying epidemic-related disruptions in the SC including the SARS epidemic. The disruptions caused by the SARS epidemic was limited at first to cancellation of business travels to the affected areas (China, Hong Kong, Taiwan and Singapore), this was followed by limited disruptions in SCs and reports of SARS-related losses by companies like Microchip Technology (Reuters, 2003; Kovar, 2003). Luckily for manufacturers, suppliers and their clients, production and international supply of goods functioned smoothly and the global SC was not affected (Siu and Wong, 2004). While global SCs have also been hit by other diseases and epidemics such as Zika virus, Middle East Respiratory Syndrome (MERS) and Ebola, they have been hit again by a catastrophic, rapid-spreading, disruptive pandemic, known as COVID.

An official Chinese government source (State Council, 2020b) reported that cases of unexplained pneumonia was brought to the attention of the Jianghan District Centre of Disease Control and Prevention in Wuhan city on 27 December 2019. Once evidence of human-to-human transmission was confirmed, the city of Wuhan was placed under lockdown on 23 January 2020 with the closure of air, rail and road transport. On the following day, travel restrictions were placed on twelve additional prefectures in Hubei province. To prevent further spread, many cities and provinces across China implemented social distancing restrictions and movement controls from 1 February 2020. By 10 February 2020, twenty-two provinces, municipalities and autonomous regions started to allow residents to return to work. Given that the period of lockdown coincided with the annual Spring Festival, the total number of days attributed to the infection was only about ten days. The pandemic across China was generally stable by mid-March except for Hubei province. The resumption rate for large-scale enterprises in China had reached more than 90% on 20 March 2020 with strong support from the government.

The rapid spread of the virus in China and the subsequent shutdown of manufacturing plants immediately sparked concerns in Australia about the risks of offshoring and procuring up to 60% of its imports from a single country (RSM Australia, 2020). The first confirmed case of COVID in Australia was a traveler from Wuhan who arrived in Melbourne on 19 January 2020. Australia shut its borders to all non-residents on 20 March 2020 and imposed social distancing restrictions the following day. Non-essential services were closed but construction, manufacturing and many retail shops remained in operation. In early June, all Australian states reported very low infection rates indicating that these restrictions were successful. However, by 20 June, the Victorian government had to re-impose restrictions following a spike in community transmission. Six weeks later, a state of disaster was declared when community transmissions continued to increase, leading to limits being imposed on the number of workers in essentials services and on the construction sector.

In response to the first round of restrictions, the building and construction industry unions and industry associations convened to prepare a set of guidelines to maintain safe operations of construction sites, ensuring the safety of workers and to assist the government in maintaining a strong building and construction industry (BCI, 2020). The directions for the building and construction industry during the second round of restrictions were more stringent. Construction of critical and essential infrastructure, and services to support these projects were allowed to remain open for on-site works. Large scale construction defined as building projects of more than three storeys (excluding basement) were restricted to a maximum of 25% of normal employees on site compared to normal operations. The shutdown of industries in Australia shows the far-reaching impacts of the pandemic.

COVID pandemic has highlighted the risks of offshoring and imports of building materials for the Australian construction industry. The sector has recently been reaping substantial benefits by offshoring the manufacturing of building materials and components to lower production cost countries in Asia. Estimates of up to 20 percent of building components being imported has been discussed by Bleby (2020) indicating that the construction sector is highly dependent on an overseas SC with the associated benefits and risks.

The last pandemic outbreak of similar magnitude was the 1918 Spanish flu during which trade was more localised and international trade was highly restricted by tariffs. Queiroz, et al. (2020) present a systematic literature review of thirty five refeered journal papers on the impacts

of epidemic and pandemic outbreaks on commercial SCs. The only three papers (Ivanov, 2020; Ivanov and Das, 2020; Ivanov and Dolgui, 2020) that focused on COVID pandemic were predictive and broad without any focus on the China-Australia construction SC. Consequently, this study is derived from the pandemic-related future research directions pointed out by Ivanov and Das (2020) – studying reactions and changes in SCs during COVID with empirical data; estimating the impact on businesses; and quantifying the prolonged impact of a pandemic on all entities on the SC.

Therefore, this study aims to examine the impact of COVID on the supply of building materials from China to Australia specifically focusing on the state of Victoria. Three objectives have been identified for this study. First, is to map out the risks that have crystalised on the China-Australia construction SC; second is to examine the impact of upstream disruption in China on downstream activities; and third, is to assess how the timing of local pandemic outbreak impacts SC performance. Thus, three research questions have been developed.

RQ1: What are the risks that have eventuated during the COVID pandemic on the China-Australia construction SC?

RQ2: What is the impact of an upstream disruption in China on downstream activities in the SC?

RQ3: How does the timing of local pandemic outbreak impact SC performance?

The following contributions are expected from this research. The first contribution is to estimate the delay witnessed by the residential builder because of the disruption that occurred on the China-Australia construction SC due to the COVID pandemic. Second, is to show how local pandemic outbreaks and timing of opening and closing of downstream operations affect SC performance despite the length of the delay upstream. Third, is to reveal where the greatest source of risk on the China-Australia SC may materialise during a pandemic.

The remainder of this paper is organised as follows. In section 2, we discuss literature on impact of pandemics on SC performance and the economy in general. In section 3, we present our case study and the method used to quantify the disruptions. Section 4 lays out the results, followed by discussion and conclusion in section 5 and 6 respectively.

2 Literature Review

2.1 Impact of Pandemics/Epidemics on SCs

Many scholars such as Koyuncu and Enrol (2010); Green (2012); and Anparasan and Lejeune (2018) have studied how to cope with outbreaks of epidemic under humanitarian logistics. Prior to 2020, there was scant literature on the impact of pandemics on commercial SCs (Sarkis, et al., 2020). To bridge this gap, Queiroz, et al. (2020) conducted a systematic literature review of thirty-five papers that focused on disruptions on commercial SCs and logistics caused by disease outbreaks. The papers covered diseases such as COVID pandemic, Ebola, influenza, cholera, malaria, smallpox and general epidemic/outbreak control. Notably, out of the thirty-five papers, only three of them - Ivanov (2020); Ivanov and Dolgui (2020); and Ivanov and Das (2020) addressed the impacts of COVID pandemic on commercial SCs and logistics as at March 2020. These papers will be discussed below.

Ivanov (2020) provide the following management insights from simulation of impacts of COVID pandemic on SC performance:

1. Decline in performance is proportional to the duration of the upstream disruption if the pandemic outbreak is restricted to facilities in the upstream echelon of the SC.
2. If the pandemic outbreak is propagated, the timing and scale of disruption propagation will determine performance reaction (i.e., the ripple effect) as well as the sequence of facility shutdown and reopening at different SC echelons rather than the disruption length upstream the SC. The ripple effect refers to negative impacts on the business activities of companies in the SC due to simultaneous propagation of the pandemic from the originating point to other parts of the SC.
3. Positive effect on the total SC disruption duration due to backlog reductions may result from simultaneous disruptions in downstream demand and supply. The highest adverse impact on the SC performance is observed in cases with very long facility and demand disruption periods downstream the SC irrespective of the disruption length in the upstream part. In cases when the facility recovery at different echelons in the SC is synchronised in

time, the least decline in the SC performance can be observed. This positive effect (least decline) is observed because backlog reductions may result from simultaneous disruptions in downstream demand and supply.

Similarly, Ivanov and Das (2020) arrived at results similar to that of Ivanov (2020) with upstream data from China and data from distribution centres in USA, Germany and Brazil. In addition, local outbreak of the pandemic after propagation will have a simultaneous or gradual impact on reserve suppliers and sub-contracting facilities due to regional or national lockdowns (Ivanov and Das, 2020). Likewise, Ivanov and Dolgui (2020); and Ivanov and Sokolov (2013) listed 3 relevant reactions to disturbances on linear SCs which are:

1. Stability: capability to go back to a pre-disturbance state and guarantee continuity
2. Robustness: capacity to survive a disruption or chains of disruptions to sustain planned performance
3. Resilience: capacity to withstand a disruption or chains of disruptions and recover performance

Furthermore, other research papers on pandemic impacts on SCs were released after March 2020. They focused on impacts of the COVID pandemic on SCs.

Table 1. Relevant literatures on the impact of the COVID pandemic on SCs

Reference	Sector/Country	Purpose	Findings
Loske (2020)	Food Retail/Germany	Discuss changing volume and capacity dynamics in road haulage	Increasing volume of freight for dry-products in retail logistics depends on the total number of new infections per day and not on the duration of COVID pandemic
Arellana et al. (2020)	Transport/Columbia	Examine the short-term impacts on the transport system due to the various policies initiated by the government to slow the propagation of COVID	General reduction in demand for transport, congestion levels and transport externalities. Freight emerged as the most resilient transport component
Hilmola et al. (2020)	Manufacturing and Logistics/Finland	Examine the impact of COVID pandemic on manufacturing and logistics	Moderate increase in transportation costs, slight increase in inventory levels, sustenance of good customer service, concern about a second-wave and dealing with long-term uncertainties
Sharma et al. (2020)	Agriculture SC/India	Examine the impact of COVID related risks to create resilient agriculture SC organisations	Supply, demand, financial, logistics and infrastructure, management and operational, policy and regulation, and biological and environmental risks have a substantial impact in agriculture SC reliant on the organisation's scope and scale
Rejeb et al. (2020)	Food SC	Critical literature review to investigate the impact of COVID-19 on food SC	Unprecedented rise in food insecurity, SC and logistics costs; radical change in consumer behaviour and rise in food safety concerns; and enhanced awareness of food waste and importance of home-grown foods
Min and Jianwen (2020); and Yongfeng et al. (2020)	Manufacturing and logistics/China	Analyze initial impact and after-shock of COVID-19 pandemic on manufacturing and logistics	Interruption in production, unsatisfied demand and fluctuations in supply and demand, increasing bankruptcy risk to SMEs, and Chinese government subsidies to restart the economy

Other evaluation frameworks, simulation studies and prediction of effects of COVID pandemic on various SCs were developed by Grida, et al. (2020); Karmaker, et al. (2020); Singh, et al. (2020);

and Nikolopoulos, et al. (2020). Lastly, Chopra and Sodhi (2004) classified risks into disruptions (e.g natural disaster), delays (e.g inflexibility of supply source, exessive handling at border crossings and change in transportation modes), systems, forecast, intellectual property, procurment (e.g exchange rate risk and single source procurment), receivables, inventory and capacity.

2.2 Impact of COVID related SC disruptions on the economy

The reports of financial losses, cessation of business activities and massive lay-offs by countries and companies due to the COVID pandemic was unsurprising but came at an unprecedented scale. In China, the National Bureau of Statistics reported that from January to February 2020, industrial output fell by 13.5% year-on-year (Market Watch, 2020). Specifically, in a survey of building materials manufacturers across 25 provinces in China, 44% of the companies reported a break in the upstream supply of raw materials; 9% reported an unaffordable increase in the price of inputs; and 63% reported that logistics and transportation were blocked (China National Building Materials Information Network, 2020). Qantas, Australia's flagship airline, reported a 91% fall in profits from January to June 2020 (Qantas, 2020); while the Australian economy slipped into recession for two straight quarters to June 2020, the first time in 30 years (ABC, 2020). From March to June 2020 in Australia, the construction industry lost about 46,000 jobs, manufacturing industry lost about 40,000 jobs while transport, postal and warehousing laid off around 41,000 members of staff (McKingsey and Company, 2020).

3 Research Method

We examined the procurement of building materials from China for current projects carried out by a local residential builder in Melbourne, Australia. The second author in this research project was employed by the residential builder who agreed to share their procurement program with the research team. To maintain confidentiality of these commercial arrangements, the results will not identify the suppliers, nor the cost of items procured for four case study residential building projects. The building materials procured from overseas included windows, tiles, light steel frames, timber floors, kitchen cabinets and bathroom vanities. Similar quotes were obtained from local manufacturers and suppliers to obtain price and delivery comparisons. As these projects were in progress during the pandemic, many of these procurement decisions were being executed as prices, exchange rates, shipping and delivery information were fluctuating rapidly. The opportunity to obtain the prices and schedules as the pandemic surfaced in China and spread across the world and to Australia, affecting the manufacture, transport and logistics across these two countries is unique and not repeatable. The timeline of the research was divided into five periods as shown in table 2.

Table 2. Research timeline

Stage of research	Name	Period
1	Pre-COVID	the period up to 22 January 2020
2	COVID in China	from 23 January to 20 March 2020
3	Post-COVID in China	from 20 March in China
4	COVID in Australia	from March to 12 May 2020 in Australia
5	COVID in Australia 2	from 2 August 2020, onwards in Australia

4 Results

A large quantity of building products was procured or planned to be procured from China for the four case study projects. The builder has ascertained that procuring building products from China constitute significant cost savings over the purchase of these products domestically in Victoria or other suppliers in Australia. The builder recognised that purchasing from overseas would involve considerable amounts of effort to plan and coordinate the logistics of international shipping, customs clearance, compliance with Australian standards, quality assurance, and the corresponding lead time for manufacture and shipping.

Having procured previously from China, the builder was fully aware of the potential shutdown of Chinese manufacturers during the Spring Festival in late January 2020 and have accounted for these delays in their construction plan. A delay of approximately 2 weeks have been allocated in all their schedules. As shown in Table 3, the builder has reported that pre-order times from China was between 2 to 2.5 months for standard or off-the-shelf products while bespoke products may take

between 3 and 4 months. Delivery times were estimated at 21 days. In comparison, local pre-order times were much shorter at between 1 to 2 weeks while deliveries could be arranged within 2 to 3 days if the supplier or manufacturer was in Victoria.

As the COVID infections increased and spread across China, news of manufacturers being forced to shut down as their workers were required to remain at home came to the attention of many builders in Australia. Depending on the progress of these orders, manufacturers would report delays in delivery either because of stoppages in production or delays in shipping. Pre-order times were extended by half to one month to cater for the disruption to their production while the shipping times were increased by at least 14 days due to the quarantine imposed on vessels sailing directly from China by the Australian Border Force. Shipping costs declined marginally due to a drop in demand.

By the end of February 2020, many provinces in China have managed to control the spread of the COVID and have recommenced production (BBS News, 2020). Pre-order times gradually reverted to the pre-COVID duration of 2.5 months while shipping remained extended to 35 days due to the 14-day quarantine of Chinese vessels. The greatest concern at this period was the rapid decline of the Australian dollar to Chinese yuan exchange rate from 4.88 to 4.08 which resulted in a sharp 20% loss of revenue for the Chinese supplier as the contracts were denominated in Australian dollars. Amidst the chaos of the pandemic, the Chinese suppliers committed to deliver on their contracts but there were indications that further exchange rate movements may lead to price increases. Despite the improved conditions in China, concerns on exchange rate risk and future deliveries lingered on.

Table 3. Impact of COVID on building material deliveries

Key Performance Indicators (KPIs)	Pre-COVID	COVID in China	Post-COVID in China	COVID in Australia	COVID-AU-2
Order lead-times for China (months)	2.0 - 2.5	2.5 - 3.5	2.5	2.5	2.5 - 3.0
Delivery times from China (days)	21 (1)	23 - 35 (2)	23 - 35 (2)	23 - 35 (2)	23 - 35 (2,3)
Local order lead-times (weeks)	1 - 2 (4)	1 - 2 (4)	1 - 2 (4)	2 - 3 (4)	4 - 6 (4)
Local delivery times (days)	2 - 3	2 - 3	2 - 3	3 - 5	3 - 7
Exchange Rates (AUD:CNY)	4.84 - 4.88	4.88 - 4.08	4.08	4.08 - 5.05	4.93 - 5.06
Customs Clearance (days)	1 - 2	2 - 3 (5)	2 - 3 (5)	2 - 3 (5)	2 - 3 (5)
Shipping Costs (US$ per TEU)	740 - 929	753 - 949		753 - 1,082	1,094 - 1,315

Notes: (1) 14 days port-to-port; (2) includes 14-day vessel quarantine; (3) containers not returned within 7-days will incur extra charges; (4) items that need to be manufactured may take up to 4 to 6 weeks; (5) delays for x-ray scans.

From 23 March 2020, a lockdown was declared in Australia (Burke, 2020). The building and construction industry was considered to be essential and remained in operation. The fact that the construction sector employed about 10% of the Australian workforce may have played an important role in the government's decision. The prevalence of COVID in Australia brought very little change to the pre-order or delivery times for products from China while local delivery times were marginally increased due to many businesses having to implement their COVIDSafe plans. For the next 2 months, supply logistics and construction operations functioned reasonably well with very few cases of COVID infections in the construction and logistics sectors.

The imposition of stage-4 restrictions in August 2020 brought on a new set of local challenges especially when most construction projects were reduced to only 25% of their on-site workforce. Local delivery times remain short because these suppliers have few other jobs to supply to. However, the local pre-order lead time takes around two additional weeks because of the limited number of workers permitted in manufacturing. The limits on workforce significantly delayed the receipt of material deliveries to site. Limits on port and customs workforce also delayed customs clearance for imported products.

5 Discussion

In view of the results obtained, this section will discuss the SC disruptions and risks that materialised; the impact of an upstream disruption on downstream business activities and on key characteristics of the SC; and how the timing of local epidemic outbreak impact SC performance.

5.1 Supply chain disruptions and risks

As depicted in table 3, the risks that materialised from the onset of COVID pandemic in China to August 2, 2020 are disruption of production, delays, increase of shipping costs and loss from foreign exchange. These eventuated risks from our results have been reported by Min and Jianwen (2020); Yongfeng et al. (2020); Arellana et al. (2020); Hilmola et al. (2020) and Chopra and Sodhi (2004). When COVID was restricted to China, the disruptions witnessed were exacerbated in Australia by high dependence on China as a single source of supply for building products which were not manufactured in Australia or were too pricey to be procured locally. Hence, an unexpected massive shift to local SCs may have created more demand than local suppliers could meet. When COVID spread to Australia, disruptions were caused by local lockdowns and reduction in construction workforce to contain the spread of the pandemic. While disruption risk is concerned with the capacity of the upstream manufacturer to produce, delays occur after products have left the originating upstream factory. Reduction in transport demand and capacity, mandatory quarantines, and other extra custom checks contributed to longer delays on the China-Australia construction SC.

Figure 1 shows the shipping cost for a standard twenty-foot equivalent unit (TEU) container from the port of Shanghai to major ports in Australia. Shipping cost was maintained at a steady level of approximately US$940 per TEU leading up to the Chinese Spring festival that commenced on 23 January 2020. A combination of the shutdowns during the festival and the impact of the pandemic led to significant declines in the demand for freight transport and the consequential fall in shipping costs from a high of US$949 to a low of US$753 by 20 March 2020. Once the Chinese government declared that the restrictions were over and manufacturing capacity was restored, these freight rates jumped by nearly 20% to US$899 the following week and had continued to gradually increase to a high of US$1,529 on 25 September 2020. Shipping cost is predicted to increase in the near term.

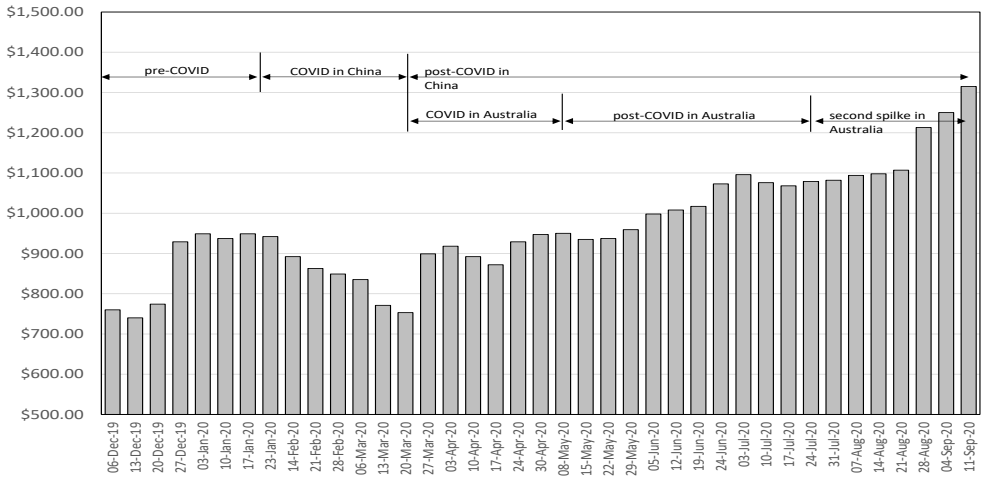

Figure 1. Shipping cost from China to Australia (Source: http://info.chineseshipping.com.cn)

By July 2020, utilisation rates for ships in the port of Shanghai exceeded 95% indicating that manufacturers in China have not only fully recovered from the effects of the pandemic but are exporting to foreign markets to supplement the loss of local production in many other countries affected by the pandemic. In comparison, the freight costs 12 months earlier in August and September 2019 were between US$590 and US$920 per TEU.

Both importers and exporters were exposed to movements in the currency exchange rate and impacted when these rates fluctuated rapidly in response to economic uncertainties. The AUD:CNY exchange rate was extracted from Yahoo finance and plotted in Figure 2 for the period of interest. The Australian builder reported that all their contracts were denominated in AUD therefore limiting their exposure to exchange risks. The Chinese suppliers were evidently exposed to currency fluctuations of more than 20% during this period. These rapid changes in AUD:CNY exchange rate also posed a challenge to the collection of goods and services tax (GST) on imported goods.

According to the Australian Border Force (ABF), the customs value of imported goods must be expressed in Australian currency or converted into Australian currency at the rate of exchange prevailing on the day of export (ABF, 2020). This would have created additional problems had the supply contracts been denominated in CNY.

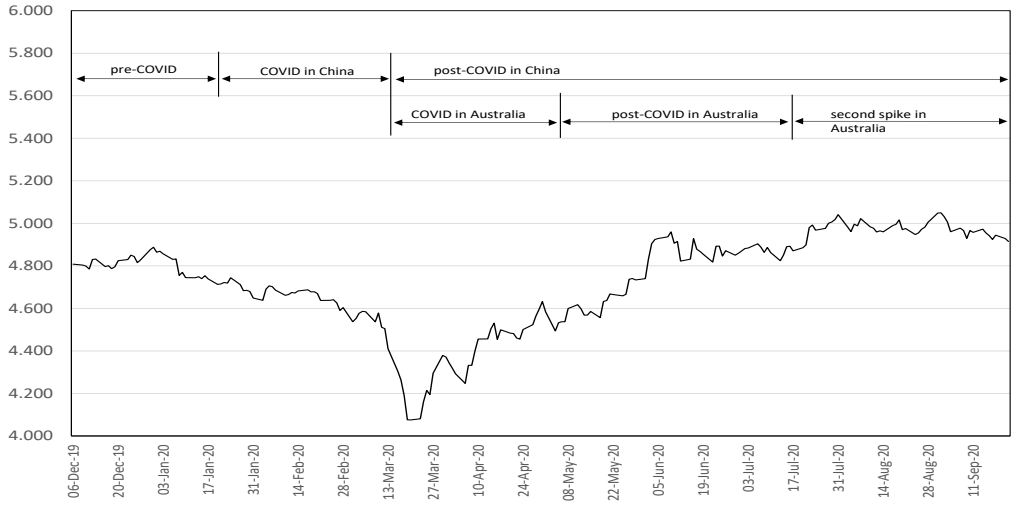

Figure 2. AUD-CNY exchange rates (Source: Yahoo Finance)

To summarise, disruption of production, delays, increase of shipping costs and adverse movement of foreign exchange were the risks that crystalised on the China-Australia construction SC of the four case study projects. These risks were managed properly for the four case study projects in the short-term due to the shorter duration of the projects. Hilmola et al. (2020) confirm that managers in Finland skillfully managed the short-term pandemic risks but were more concerned about a second wave and dealing with long-term uncertainties. Uncertainties like changes in transportation mode can cause further delays and unfavorable adjustment in the SC (Chopra and Sodhi, 2004); while a second wave will cut demand and lead to loss of revenue (Ivanov, 2020).

5.2 Impact of an upstream disruption in China on downstream activities in the SC

The discussion will start from stage 2 (COVID in China) because during stage 1 everything was normal. In stage 2 (COVID in China), the initial impact of the upstream disruption was limited to China without propagation along the SC. It was estimated that the total delays due to the shutdown of manufacturing and transportation in China was limited to approximately 10-14 days partly because of the Chinese Spring festival. However, generally the SC witnessed longer disruptions otherwise known as ripple effects as shown by KPIs; lead time increased by 0.5month to 1 month (25% to 40%), delivery time increased by 2 to 14 days (10% to 67%) and custom clearance days increased by 1 day (50%). Our findings correlate with that of Ivanov (2020) as the total delay (ripple effects) experienced by the builder was around 14 days witnessed at the upstream facilities in China.

Stage 3 (Post-COVID in China) and stage 4 (COVID in Australia) occurred simultaneously. The efforts by the Chinese government, eager to promote economic recovery, put in place recovery plans in six key areas including employment, finance, foreign trade, foreign investment, domestic investment and market confidence were very effective. Subsidies provided for the logistics sector include a three-month exemption of port fees for cargoes, reduction in port security fees, and reductions in railway, airport and insurance fees (State Council, 2020a). Other general palliatives rolled out include tax relief/reduction and CNY20 billion support fund to small and medium scale businesses in the most impacted city of Wuhan (Min and Jianwen, 2020). This support from the government helped the recovery of lead-times from a peak of 3.5 months to 2.5 months, although less than the normal pre-COVID 2.0 months.

Delays emanating from Australia were centred on increased screening of vessels and health checks on the crews that have departed from mainland China. It was reported that the freight sector in Australia was facing a crisis (The Age, 2020) as many goods shipped from China and elsewhere could not be sold at the stores, were stacked up to capacity at warehouses and container parks. Ivanov (2020) predicted the lowest decline in SC performance due to longer delays in epidemic propagation and shorter disruption durations downstream the SC. This is because of the time lag between dispatch from factory and arrival at distribution centers. Our findings confirm that stage 3

and stage 4 had the lowest decline in performance. Notably, the factories in China were recovering at this stage due to the containment of COVID; and Australian importers were receiving the backlog of orders with lead-times of 2 to 3 months.

Aside from impact on business activities on SC, these disruptions and risks adversely impacted the key survival characteristics of the SC. The stability of the SC was adversely affected as lead-times; delivery times and custom clearance days fell well below pre-COVID levels. The continuity of the SC has not been threatened because government assistance in both China and Australia has played a key role in ensuring businesses remain a going-concern and continue SC transactions. The SC is not robust because planned performance was not sustained majorly as the lockdown in Victoria was prolonged and massively reduced construction activity which aligns to the modelling of Ivanov (2020). The operational components of robustness are reserves, time floats, safety stocks and extra facilities and capacity reservations (Ivanov and Sokolov, 2013) which were all missing in the SC amid the disturbance. The resilience varies across different echelons of the SC. The manufacturing and logistics in China have recovered their performance to a reasonable extent while Victoria is still emerging from a second wave and gradually lifting restrictions. Overall, the SC is yet to prove its resilience partly due to difference in approaches by the Chinese and Australian governments in handling the pandemic; and partly because of separation of powers within Australia where the Victorian state government has the power to impose and lift restrictions within its jurisdiction. The disruptions adversely affected the stability, robustness and resilience of the SC, the three main survival characteristics of linear SCs identified by Ivanov and Dolgui (2020)

5.3 How the timing of local epidemic outbreak impacts SC performance

The China-Australia construction SC was synchronised in time when COVID was limited to China as the builder utilised the materials that were already dispatched from China with little or no disturbances. However, from March 20 to May 12, 2020 during the first wave of COVID in Australia, there was little or no synchronisation because Chinese manufacturers had not produced at all for 2 months. There was little done on orders received from middle of January because of the Chinese Spring festival holiday and subsequent lockdowns. The impact was serious because the builder experienced delays of up to two weeks in receipt of imported materials.

The impact during the second lockdown in Victoria (stage 5) where many warehouses were closed or had reduced staff numbers under the very tight restrictions was the most severe on the builder. Truck loading rates were reduced by 30% to 40% due to the reductions in workforce. Emptied containers could not be returned because there were fewer workers to unload the goods from these containers: attracting extra charges. Data from the Shanghai (Export) Containerised Freight Index (SCFI) reported that in contrast to global “on-time rate index”, both port and product on time performance for Australia and the port of Melbourne declined significantly during the month of July followed by another fall in August 2020.

Also, the workforce on medium and large construction sites were slashed by 75% while small-scale construction was restricted to a maximum of 5 people on site. Three out of the four case-study projects were small-scale projects and were marginally impacted by workforce reduction with additional delay of two weeks. The remaining large-scale project was delayed by an extra four weeks. This shows that the second lockdown in Victoria had an asymmetrical impact on small, medium and large-scale projects which corroborates the findings of Hilmola et al. (2020).

The China-Australia construction SC, especially in Victoria recorded the worst performance from May to August 2020 due to desynchronisation caused by the second lockdown in Victoria. The timing of the second lockdown did not match with the reopening of factories in China, rather Chinese manufacturers opened, produced and shipped while Victorian ports, transport lines, warehouses and builders were totally shutdown or working at less than 30% capacity. Also, the economic uncertainties which culminated in consecutive quarter to quarter recession in Australia reduced demand for building projects further creating more disruptions in shipping volume in the SC. These findings agree with the forecast of Ivanov (2020) that the highest adverse impact on the SC performance is observed in the cases with very long facility and demand disruption periods downstream the SC irrespective of the disruption length in the upstream part.

6 Conclusions

This study carried out during the pandemic from March to September 2020 categorised the offshoring risks that have eventuated on the China-Australia construction SC during the COVID

pandemic and quantified their impact on SC performance. SC risks due to the pandemic include the shutdown of manufacturing plants; the restrictions on transportation during the spread of the virus in China; and transportation delays, quarantine by customs and shutdowns when the virus spread to Australia. However, due to efforts by the Chinese government to contain the spread of the virus and subsequent incentives to rapidly restore production capacity, the impact of these delays for the delivery of products to Australia was limited to a maximum of two weeks.

Risks of exchange rate fluctuation and shipping cost were not considered significant by the Australian builder as the supply contracts were denominated in AUD. The increment in shipping costs, on the other hand, were paid by the Australian builders. The maximum impact of these risks was about 20% of revenue for currency fluctuations and US$550 per TEU for shipping costs.

The upstream disruption in China was short and restricted which had a limited impact on the SC. The greatest impact arose from the prolonged lockdown in Melbourne which led to desynchronisation in SC activities in China and Australia. The large-scale project considered experienced additional delay of four weeks while the other three small-scale projects were delayed by three weeks. This shows that desynchronisation in SC had a more serious impact on the large-scale project. Thus, during a pandemic outbreak, the greatest source of risks on the SC may not be the originating point of the disease, it could be anywhere on the SC depending on the stability, robustness and resilience of each part. The building and construction industry must utilise their experience from this pandemic to manage future SC risks. A similar future study with a larger sample size of small, medium and large-scale projects will produce a more generalisable outcome.

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