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IMPACTS OF COVID-19 ON CONSTRUCTION SUPPLY CHAIN

by

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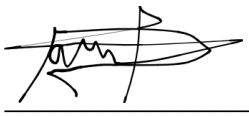

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ABSTRACT
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COVID-19 pandemic is deemed to be the largest global health crisis since decades. Aside from the unprecedented number of deaths, the pandemic has led to significant economic slowdowns, severe business disruptions and serious difficulties. COVID-19 has a dramatic impact on global economic development and various industries. Being the countries' most important economic factor, the construction industry has encountered many challenges since the early stages of the pandemic. This research helps in manifesting precisely and comprehensively the impacts of COVID-19 on the construction sector, particularly the construction supply chain. It identifies the disruptions that were encountered at different levels of the supply chain, and discusses the challenges that were felt at each stage of the procurement process of building materials. It also addresses the contractual and legal approaches that emerged in response to the pandemic impacts. Therefore, the study findings will be helpful to industry stakeholders who are interested in understanding the early effects of the pandemic on the construction industry, and to those who want to build upon the reported findings and establish necessary preliminary grasping on how to deal with such disruptive scenarios.

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CHAPTER 1

INTRODUCTION

1.1. Background

Coronavirus, COVID-19, quarantine, self-isolation, lockdowns, restrictions, and many other terms have emanated as new vocabularies around the world, not excluding the construction industry. Exactly a decade has passed since humanity's last pandemic (Ogunnusi and Salman, 2020). However, in 2019, the most common disease outbreak called Corona Virus or COVID-19 has emerged, infecting all countries worldwide within few months, and was declared a pandemic in March 2020 by the World Health Organization (WHO, 2020). Due to the severity and rapid spread of this outbreak, industries started suffering significantly from uncertain conditions, especially because of the worldwide lockdown (Hao et al., 2020; Bartik et al., 2020).

Historically, many disasters have occurred and disrupted the economy and development of various industries. These included the draconian flood in Thailand, which resulted in the loss of 0.5 million businesses and around 2500000 jobs (Asgary et al., 2020), the severe earthquake in Turkey that damaged $ 4.5 billion of investments by small-medium companies, in addition to the extreme Indonesian tsunami in 2004 and hurricane Harvey in 2017 (Rathore et al., 2008, Eggers, 2020). And on top of that, falls the outbreak of COVID-19 which has been the major disruption since 2019, severely hitting all economies all over the world, regardless of their size and development phase (Badman, 2020). The key difference between COVID-19 and the previous disruptive events is that this pandemic and its ramified serious effects were deemed completely unforeseen. Firms and organizations normally tend to tolerate low-probability- high-

impact events, but lack readiness for such extremely uncertain risks (Heckmann et al., 2015). Even though local epidemics have been discussed as a possible source of risk in the supply chain risk management (SCRM) literature and have frequently disrupted supply chains during the last decades, a global pandemic such as COVID-19 was considered an unlikely event (Hilderink, 2020).

COVID-19 has brought critical challenges to the development of the global economy and especially to the construction industry, which has been severely affected by the adverse impacts (Ogunnusi et al., 2020). Restrictions on construction projects due to the pandemic crisis have slowed economic growth, increased unemployment, disrupted the supply chain for construction materials and increased investment losses (Bsisu, 2020). According to estimates, the growth of international construction has decreased from 3.1% to 0.5% in the current year (Global Data, 2020).

Many countries have ceased production of construction materials since the early stages of the pandemic (DBS Group, 2020). During January and February 2020, manufacturing in China was disrupted due to the lockdown orders. Inventories tend to last about a month, so the industry felt the most supply disruption in late February and early March. Since then, things have improved a little in China but much worse worldwide (Weinfass, 2020), since for example, and according to conservative estimates, about 30% of the US construction product imports come from China, whereas some builders rely on China for up to 80% of their materials and goods, due to its low prices (Goodman, 2020). Such early declines in production, combined with the continuous impact of the pandemic on the construction supply chain and economic activity in general, have resulted in a strong combination of volatility and price increase for many construction materials and products (Ellis and Trentacosta, 2020).

1.2. Problem Statement

While many publications and researches have addressed the topic of COVID-19 and its various implications, as it has been the most disastrous issue hitting the world for the past two years, the predominant focus was directed towards the impacts of the pandemic on the healthcare sector, commodities and psychological effect on the population. However, unfair attention was given to the implications on the construction industry as it was deemed among the least affected, when in fact it was severely disrupted since the early stages of the outbreak. Also, and while some authors and professionals have discussed the impact of COVID-19 on construction, they mostly focused on the contractual aspect of things. None have discussed deeply to what extent the pandemic has affected the construction supply chain and the materials procurement process, which are considered a major component in any project. Moreover, and in addition to the contractual side, the legal impact of such type of disruptive event has not been a main concern for authors, and no important discussions were conducted in this regard.

1.3. Research Objectives

The main objective of the research is to manifest comprehensively the impacts of COVID-19 on the construction supply chain, and identify precisely the constraints that have broken its continuity. The research explores the disruptions that had hit the procurement of building materials and products, and depicts the issues and concerns that were present at each stage of the procurement process. Therefore, this study addresses the project management challenges that have been encountered during the whole pandemic period by project stakeholders and especially contractors. Moreover,

the research discusses the contractual and legal approaches of the impact of COVID-19 on the construction supply chain, and highlights the contractual clauses as well as the position of the law towards this situation.

1.4. Methodology

For the purpose of achieving the mentioned objectives, the following methodology is followed throughout the research:

1. Establish a comprehensive and solid understanding of the topic by conducting a profound reading of the Construction Supply Chain literature review, encompassing a wide range of journals, articles, books, websites, etc.
2. Conduct an in-depth analysis of what was reported in the COVID-19 and construction industry related literature, documenting the impacts, of the pandemic on the construction supply chain.
3. Provide a thorough representation for a typical supply chain framework, showing all the steps and scenarios of the end-to-end process, and carry out a mapping for the reasons previously discussed.
4. Discuss the effect of the legislative directives and acts that were issued in response to the pandemic, from both the contractual and legal perspectives.
5. Put forward a consolidated summary of the research work, as well as conclusions and recommendations. Limitations of the provided solutions will be explored and future work will be suggested.

1.5. Significance of the Research

The research serves a significant contribution in determining the implications of COVID-19 on the construction supply chain. It identifies various factors that led many firms to halt their works, due to the disruptions and breakdowns in their supply chains and their materials procurement processes. It also explores the effect of the measures imposed by authorities during the pandemic period, from both contractual and legal points of view. Thus, this study delivers several benefits to all stakeholders and especially to contractors who usually find themselves in a risky position when such disruptive events occur. Also, it provides strong support for project management teams in preparation for similar future disruptions.

CHAPTER 2

LITERATURE REVIEW

2.1. Construction Supply Chain

Construction Supply Chain is a term used to describe the connection between different companies and stakeholders that turns a set of products, basic materials or services into a finished product to be delivered to the client (Segerstedt and Olofsson, 2010). It refers to controlling the flow of information, logistics, and capital from the purchase of building materials, the completion of subprojects, the completion of projects, and their subsequent use and maintenance. In this process, the client, general contractor, designer, subcontractor, material supplier, and all other project stakeholders are linked to a functional network chain structure (Liao, 2019). And due to the project-based nature of construction and the way procurement normally works, they are usually members of several supply chains for different projects (Segerstedt and Olofsson, 2010).

2.1.1. Characteristics of Construction Supply Chain

The construction supply chain has unique features that differentiate it from other supply chains and make it more sophisticated. It is characterized by being converging, where the end user is a limited number of clients or even only one client; typical make-to-order, where a new product or prototype is created by every project; and temporary as the partnership between project participants is a short-term partnership (Vrijhoef and Koskela, 2000). Moreover, construction projects can be very large projects, and thus the construction supply chain can be very complex, especially that the construction industry

is project-based and of discontinuous nature, hence it is difficult to take advantage from economies of scale and learning. This complexity, which is one of the key features, can be referred to the various on-site materials and stakeholders (subcontractors and suppliers) needed to execute the project (Al-Werikat, 2017).

In construction, the major company that manages the construction project usually accomplishes only a small portion of the overall product with its staff and production equipment, however, most of the product value, about 75% or even more in many cases, is built with the help of subcontractors and suppliers (Dubois and Gadde, 2000). For instance, in 1999, more than 3,000 subcontractors and suppliers were involved in projects that Wates Construction Company had delivered (Scott et al, 2001). In addition, most of the construction costs are material costs, thus optimizing such costs can return with significant economic benefits. Hence, the main material costs of construction projects need to be tightly controlled. And according to Hasim and Yusof (2018), the products and services provided by construction firms in a construction project generally account for roughly 80% of the total project cost.

2.1.2. Types of Products

The construction supply chain involves three types of products: stocked-standard products, make-to-order standard/configurable products, and custom products (Cheng et al., 2010). The stocked-standard products are standard finished goods, such as wires and tubes, that are built in advance based on the sales forecast and historical demand, and stored in the supplier's warehouse (Kuo-Hwa Chang and Yang-Shu Lu, 2010). These products are usually in high demand and have a low inventory cost. This type of supply chain is stock-based, and the product is produced before the supplier

receives the order. Thus, an unsatisfied order is usually a loss of sales because alternate suppliers are often found. These products are delivered by the suppliers to the site or the subcontractor's warehouse.

The make-to-order standard/configurable products are slightly configured and customized goods, built once the order is received and the buyer usually pays for all the ordered units (Gupta and Benjaafar, 2004). This type includes products that are created for specific designs and goods that are manufactured, assembled, or slightly configured from standard products (Kuo-Hwa Chang and Yang-Shu Lu, 2010). The vendors might choose this type of products for a variety of reasons, as they prefer to maintain flexibility to slightly customize the product in accordance with the requirements of a particular customer orders. Some products, for example, such as switchgears, have high depreciation rates and holding costs, and so there is a risk of keeping stock for uncertain estimated demand. In addition, vendors who supply products such as light fixtures generally avoid storing stocks, because they usually release various products in their catalogs, and hence it will be difficult to predict the demand for each particular design. Therefore, production, assembly or configuration of these on-demand standard/configurable products will only commence after a customer order has been received and confirmed. The construction supply chain for make-to-order products includes site supervisors, subcontractors, distributors and manufacturers (Cheng et al., 2010).

The third type comprises the special designed and engineered goods that are also built once the order is received, and the buyer pays for all the ordered units. While the previous make-to-order products include standard products that are built or configured in response to customer orders, this type involves design, development, and

manufacturing of products, depending on customer request. HVAC and custom duct systems are examples of custom products. Some standard ducts may be in stock or slightly configured, but duct systems with special features and sizes must be designed prior to production. The customized MEP product supply chain typically consist of field foremen, subcontractors, plants, and suppliers. The plant is a business unit for the design and manufacture of custom products, where it may be a division of supplier or subcontractor, or a third party company. In this case, suppliers, plants and subcontractors cooperate with each other in the process of negotiation, design, procurement, production and delivery. Also, engineers and architects with special requirements can also participate in the negotiation, design and manufacturing processes. Finally, the detailed design usually begins after the customer's order has been received and validated. Thus, the supply chain for such type of products is often driven by customer needs and specifications and takes a long time to finish (Cheng et al., 2010).

2.1.3. Procurement Process

Procurement represents the process of acquiring goods and services, from the preparation and processing of requests to the receipt and approval of invoices for payments. The procurement department is in charge of issuing the purchase orders and initiating the flow of materials (Monczka, 2010). It also involves various types of acquisitions (contracting, rental, leasing) and the task associated with the identification and selection of suppliers, negotiation, performance monitoring, order analysis and material flow management (Hasim and Yusof, 2018).

Managing purchase time, location, and number in the building material purchasing process leads to purchase risk when contracting external projects. Purchases are long-term and play a significant role in project progress, quality, and cost control throughout the project life cycle. Only by closely understanding the purchasing relationships and managing purchasing risk can the goals of quality, and cost be effectively supported (Liao, 2019). The raw materials required at the construction site are restricted by site conditions, capital and construction performance. Also the number of purchase batches and the quantity in each batch is essential. This inevitably leads to adverse effects if the material cannot be delivered on time and does not meet construction progress and quality requirements. Appropriate batch size is essential for reducing work in progress and buffers within the system's interfaces. The small batch size allows to quickly identify and fix production problems, facilitating workflows across different workstations in the production network (Hopp and Spearman 2000).

Another issue in the process of purchasing construction materials is the nature of the material and its function, which complicates the process of selecting a supplier. Different construction materials have to be procured from various suppliers. Both quality and quantity require a lot of time-consuming inspection processes. In addition, increased purchase time impacts not only the progress, quality and cost of project construction, but also the timely delivery of materials, thereby delaying project deadlines (Liao, 2019).

Material procurement process must be well implemented in order to avoid supply delays (Hasim and Yusof,2018). Purchase risks can be efficiently mitigated by establishing a proper supply chain for the project, building strategic cooperation and forming an efficient long-term work system, particularly by evaluating existing

suppliers, and suppliers with decent performance and long-term stable raw materials (Frimpong, 2003).

Strategic alliances with suppliers can secure the performance and quality of materials, gradually lessen the inspection process, and form mutual trust and interdependence collaborative relationship. Strategic partnerships minimize transaction costs, and drive construction progress and quality improvements (Liao, 2019).

2.1.4. Inventory Management

Material management is one of the important aspects of a construction project, accounting for approximately 55% to 60% of the total cost of construction. Effective material planning of materials is the key to a successful project. Material management is the process of providing the right quantity of materials, with the proper quality, in the right place, at the right time. It involves the processes of material planning, material procurement, material storage and inventory control, handling and transportation (Pitroda, 2015). Material planning and inventory control are categorized as the two most crucial parts of material management.

The purpose of inventory management is to maintain sufficient inventory of materials to meet the anticipated demand for a particular financial investment. Proper management is essential to keep the materials in good condition and ready for use (RathinaKumar et al., 2018). A major portion of construction costs is material costs, so optimizing material costs can return with significant economic benefits. Therefore, the main material costs of construction projects need to be tightly controlled (Hasim and Yusof, 2018). Materials compose a component that require special attention when creating a master plan for a project and during the progress of daily construction. Lack

of needed materials is a major reason behind reduced productivity at construction sites. Ineffective material management can cause a 50% increase in working hours. Therefore, a detailed plan for material management for each and every construction project is absolutely essential.

The material cost is impacted by several parameters including purchase costs, holding costs and shortage costs (Abdul-Malak, et al., 2000). Purchase or ordering costs include supplier selection costs, communicating order costs, transportation costs, etc. Holding or carrying costs encompass storage costs, handling costs, spoilage costs, taxes, insurance, etc. When ordering a bulk quantity, money related to purchase and administrative costs can be saved, as well as shortage or unavailability costs, but on the other hand, this imposes additional holding costs.

RathinaKumar (2018) relates the optimum quantity per order to this equation:

$$Q = \sqrt{\frac{(2*O*D)}{(H*U)}}$$

Q – Order quantity; number of units per order

O – Ordering cost

D – Demand Rate

H – Holding cost

U – Unit cost of the material

Purchase and holding costs are exactly opposite to each other. If there is too much inventory, the holding costs will increase, however, a large number of purchases will result in higher ordering cost.

2.1.5. Modes of Construction Supply Chain

In any construction project, and in order to acquire a certain product and have it delivered from the supplier to the site, the delivery process should follow or adopt a certain mode. This mode is selected by the contractor based on several factors (Abdul-Malak, et al., 2000). The three main supply chain modes are: Instantaneous, Manufacturing and Just-in-time modes.

2.1.5.1. Instantaneous Mode

This mode of construction supply chain is a strategy that construction companies adopt to maintain large inventories on hand (Jiang et al., 2021). This mode aims to minimize the chance of a product or material to be out of stock (Banton, 2021). By practicing this strategy, higher holding or carrying costs are incurred because of the large quantities of inventories.

Instantaneous mode entails that project materials and products are to be ordered well in advance, and stored in the warehouse before they are installed. This mode is common and widespread in less industrialized countries. Those countries prefer to adopt such mode because of the poor transportation infrastructure or poor quality control for example, or they are exposed to natural disasters that might disrupt and delay the delivery and transportation process (Banton, 2021). Therefore, and to avoid any kind of risk that might end up delaying the availability of materials on site at the time to be executed, companies tend to pay for the excess inventory. Moreover, they reorder material before reaching a minimum level in order to be able to continue carrying their works whilst the new batch is being supplied (Abdul-Malak, et al., 2000). This is essential particularly in the cases where the lead time, which is the time from when the

firm places the order until the material enters the site, is long. Also, by adopting this mode, a minimum level of inventory is kept on hand for the case of emergencies. In some cases, the instantaneous mode is deemed costly, especially when it leads to waste because not all the quantity of the inventory is being consumed, beside the additional handling and storage costs (Banton, 2021).

Usually, the ordered products require shipment because companies might head for international suppliers, hence, this mode can be considered beneficial as the lead time might be long in this case. But it is crucial that the construction program should be updated frequently to alter the shipment dates in case the schedule has changed (Abdul-Malak, et al., 2000). Furthermore, transparency of the inventory is essential to determine the available materials and thus the amount that should be ordered. Eventually, the materials should arrive to the site before the planned early start of the activity, otherwise delays in the schedule will occur (Sfeir, 2000). In many cases, the material might need on-site fabrication before being installed. Figure 1 shows a typical procurement program for an instantaneous mode.

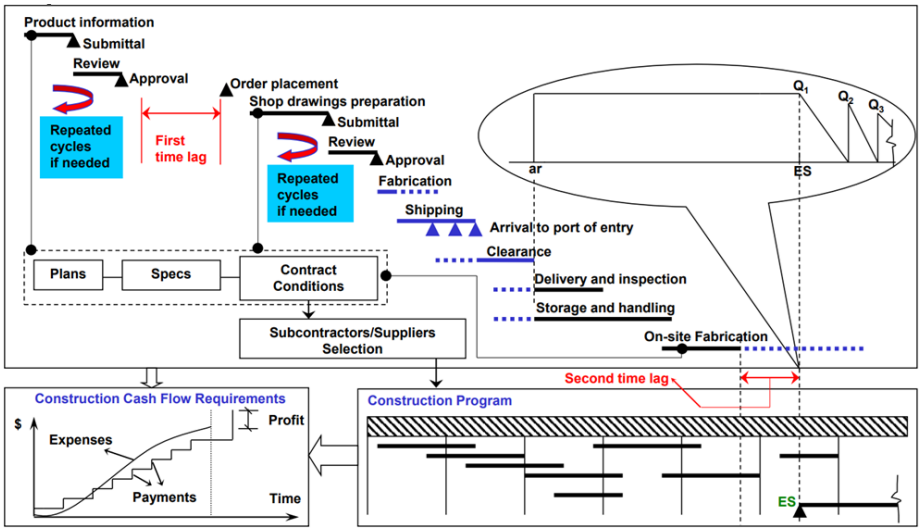

Figure 1: Typical Procurement Program (Sfeir, 2000)

2.1.5.2. Manufacturing Mode

In manufacturing construction, the components are manufactured in the factory or plant, transported to the construction site as complete or semi-finished assemblies, where they are assembled and installed according to the design. Compared to instantaneous mode, manufacturing construction mode has the benefits of increased productivity, shorter project duration, safety and improved environment (Jiang et al., 2018).

Proper logistics of the manufactured or prefabricated components from the offsite factories to the construction site is critical to the efficiency and performance of this mode of supply chain. Prefabricated components are usually large in size, heavy and bulky, which can lead to uncertainties such as alterations in storage space requirements, delivery times, and corresponding costs. Therefore, improper delivery of those components can decrease the supply chain performance in terms of productivity, cost and duration (Wang et al., 2019). Moreover, the late delivery can delay on-site works, prolong construction time, and increase project costs, whereas on the other hand, the early delivery to the construction site can lead to layout needs, lack of storage space, or high on-site crane handling costs. It is highly desirable that the same type of manufactured products to be transported to the site in the exact quantity and quality at the right time, so that resources related to inventory and the usage of cranes for double handling can be considerably saved (Lu and Yuan, 2013). Also, if too many parts are delivered at one time, the limited resources at the site will not be able to handle them all at once, and thus the construction site will be congested, the delivery time will be long, and the delivery drivers will have to wait for the time window of these components in case the required resources are not available (Pheng and Chuan, 2001). Therefore,

contractors do not desire the products or materials to arrive way ahead of the installation time, nor after the due date, because this will inevitably result in a loss for the entire project (Zhang and Yu, 2020).

In construction, traditional on-site construction methods have been criticized for their low productivity, large amount of waste and low level of safety (Khahro et al., 2019). Compared to the conventional mode, manufacturing or precast construction has the major preference of less workload, improved quality and productivity, and more safe and enhanced environment under controlled conditions (Yin et al., 2009).

The Crown House Engineering manufacturing center in the UK primarily manufactures integrated heating, ventilating and air conditioning modules. During the 1990's, products and processes were analyzed, resulting in regulation of product design and manufacturing, achieving year-to-year improvements (Pasquire and Connolly, 2002). Over the course of 18 months, the design and manufacture of the integrated module was modified, generating the following value-added improvements:

Table 1: Multi-Service Fan Coil Module (original product)

Application	**Labour Hrs**	**Materials £**	**Totals £**
Framework	9.62	91.84	234.22
CHW & LTHW Mechanical Services	35.00	317.60	836.49
Condensate	2.53	15.03	52.47
Electrical Containment	1.10	0.00	16.28
Ventilation Services	4.00	0.00	59.20
GRAND TOTALS	**52.25**	**424.47**	**1,198.66**

Table 2: Multi-Service Fan Coil Module (new product)

Application	**Labour Hrs**	**Materials £**	**Totals £**
Framework	2.92	31.20	74.42
CHW & LTHW Mechanical Services	10.64	313.34	470.81
Condensate	2.43	14.72	50.68
Electrical Containment	1.10	0.00	16.28
Ventilation Services	4.00	0.00	59.20
GRAND TOTALS	**21.09**	**359.26**	**671.39**

Table 3: Cost Savings

Application	Original Product	New Product	Cost Saving	%age Difference
Framework	£234.22	£74.42	£159.80	
CHW & LTHW Mechanical Services	£836.49	£470.81	£365.68	
Condensate	£52.47	£50.68	£1.79	
Electrical Containment	£16.28	£16.28	£0.00	**0%**
Ventilation Services	£59.20	£59.20	£0.00	**0%**
GRAND TOTALS	**£1198.66**	**£671.39**	**£527.27**	**44%**

2.1.5.3. Just-In-Time Mode

The Just-In-Time mode or strategy involves more frequent deliveries with smaller quantities of materials in each batch. The supply chain mode a management strategy that helps minimize waste resulting from overproduction, waiting times, transportation, inventory, and manufacturing of defective products (Akintoye, 1995). The adoption of such system in construction, where material shortages are very important, should be carefully considered. Once implemented, usually a small amount of material arrives at the site just before it is processed or installed. The schedules should be frequently updated in order to inform the supplier about any modifications that might affect the delivery times (Abdul-Malak, et al., 2000).

JIT delivery saves onsite resources associated with second handling (interim storage areas, cranes, labor, etc.), hence reducing environmental emissions through corresponding energy savings (Kong et al., 2018). Moreover, in excessive density cities such as Hong Kong, construction sites don’t have sufficient spaces to stock a lot of components before assembly (Ko, 2010). For instance, more than 80% of the building contractors in Hong Kong face difficulties and challenges in storing materials due to storage space constraints (Pheng and Chuan, 2001).

The JIT mode entails that components of exact type have to arrive to the construction site in the right quantities and at the right time in order to avoid any delay in the installation process. A precise coordination of the arrival time of the material and the availability of handling resources is required and essential (Zhang and Yu, 2020). Therefore, to improve sustainable performance, the number of delivery batches, the quantity each delivery batch, and the delivery times should be optimized (Kong et al., 2018). Delayed delivery by suppliers is a common problem faced by general contractors. Therefore, they prefer to have a reserve stock of materials on the site based on a layout plan prior to installation. Hence, it is necessary to adjust the JIT strategy in a way to ensure a minimum level of time buffer to mitigate the possibility of delays, taking into account the harsh and diverse conditions of the construction site (Pheng and Chuan, 2001). Most of the contractors desire a time buffer of one to two days, or three to five days depending on the space constraints on-site (Zhai et al., 2018).

2.1.6. Supply Chain Disruption Risks

The construction supply chain is extremely fragmented, and includes both small and medium-sized suppliers and subcontractors (Briscoe et al., 2001). In most cases, materials have to be imported (especially in the developing countries) and this makes the supply chain global, more challenging to manage, and consequently, prone to inevitable risks and disruptions (Darko et al., 2016).

Supply chain risks can be categorized into operational risks and disruption risks (Ivanov, 2018b). Operational risk relates to daily disturbances in the supply chain operations such as demand fluctuations and lead time issues, whereas disruption risks fall under low-frequency but high-impact events, characterized by their immediate and

sharp effect on the structure of the supply chain network design, as some suppliers, factories and transportation routes become unavailable for a certain time (Ivanov, 2020). Although many companies have promoted plans to prevent recurring low-impact risks in their supply chains, many others have ignored high-impact, low-probability risks (Sheffi and Rice, 2005).

Disruption risks might involve natural disasters like tsunamis and earthquakes (for example, the 2011 tsunami in Japan), man-made disasters (such as the BASF factory blast in Germany in 2016), in addition to terrorist attacks and wars (the Gulf War on September 11, 2001), strikes (as in France against the increase of retirement age on October 2010), legal disputes, and events related to social security (Sodhi and Tang, 2012). Stecke and Kumar (2009) showed that the economic losses and frequency of natural and man-made disasters have increased significantly. The following table 4 shows the likelihood and severity of different disruptive events on the construction supply chain.

Table 4: Risk Analysis Matrix for Catastrophes

Event	Likelihood	Severity	Risk level
Disruption to transportation media	Very	Very high	Extreme
Supply breakdowns	Very	High	High
Trade union actions (strikes)	Very	High	High
Flood	Very	High	High
War and mass killing	Little	Very high	High
Tsunami	Somewhat	High	High
Recession	Somewhat	High	High
Unexpected departure of key employees	Very	Average	High
Health hazards	Somewhat	Average	Medium
Extreme weather event (storm, rain, wind, etc.)	Somewhat	Average	Medium
Landslides	Somewhat	Average	Medium
Violence	Little	High	Medium
Attack on infrastructure	Little	High	Medium
Industrial accidents	Little	Average	Medium

Some proactive strategies can help companies reduce, or even avoid, the potential occurrence of certain types of disruptions (Stecke and Kumar,2009). Many researchers have emphasized that the implementation of robust proactive strategies can reduce the need for mitigation strategies. These strategies were discussed so that they can assist in predicting catastrophes based on advanced warning approaches. The researchers asserted that these strategies can provide companies with precious planning time to arrange their capabilities so that disruption impacts can be minimized or even completely prevented (Stecke and Kumar,2009). The redundancy and flexibility of construction supply chain components aids in the definition of coping strategies that help mitigate disasters. A serious disaster, along with lack of preventive and coping strategies, likely to lead to supply chain disruptions, and possible enterprise failure. In these situations, firms can use survival strategies that can be implemented by responding immediately to disaster (i.e. saving lives and property) and taking recovery steps (i.e. reconfiguring resources to resume the operations) (Sandanayake et al., 2018).

2.2. COVID-19 and Construction Supply Chain

2.2.1. COVID-19: A Global Pandemic

Coronavirus disease, or what is known as COVID-19, is an infectious disease caused by the SARS-CoV-2 virus, emerged in November 2019 in Wuhan, China, and was declared a pandemic on March 20, 2020 (WHO, 2020). COVID-19 has been the major disruption since 2019, severely hitting all economies all over the world, regardless of their size and development phase (Badman, 2020). It forced most countries and governments to implement lockdown measures to eliminate adverse

effects on their communities and economies, but at the same time, causing slowed global economic growth, travel bans, unemployment and restricted international trade. The COVID-19 crisis was deemed the global health crisis after March, 2020. Various organizations all over the world estimated that this pandemic will negatively impact the world GDP growth (Economic Outlook, 2020). The Asian Development Bank reported that the outbreak of COVID-19 is projected to damage global GDP by up to 4.8%. It is also possible that international foreign direct investment will decrease from 6% to 15% (Park et al., 2020). Also, the United Nations Conference on Trade and Development (2020) reported that international stakeholders need $ 2.5 trillion in bailouts to overcome the global economy. Therefore, and based on this statistic, the footprint of this world crisis is more serious than that of 2008. In addition, it is estimated that about 25 million people have lost their jobs during this pandemic, which means a loss of $ 3.4 billion (Ordonez, 2020). According to reports from the International Labor Organization (ILO), the global lockdown measures and policies have badly impacted the situations of international employees, which may result in a loss of about 80% of jobs worldwide (International Labor Organization, 2020b). Bhuiyan et al. (2020) mentioned that around three million employees could lose their jobs in the United States alone, but this crisis could affect other continents with the same statistics.

All industries have been suffering from uncertainties due to the sharp outbreak of COVID 19 since early 2020 (Hao et al., 2020). The negative impact of the pandemic on the construction sector, manufacturing, small businesses and automobile industry could be more evident than on the educational sector and social work activities (Hyder, 2020). The disease has been affecting the economies and various industries, that are facing various serious problems in terms of loss. Most industries encountered critical

challenges such as decrease in demand, disruption of commodity supply, trades shutdown, suspension of imports and exports, and shortages of raw materials due to the strict global lockdown measures (Bartik et al., 2020).

The major difference between COVID-19 and other disruptive events is that this pandemic and its ramified serious effects were deemed completely unforeseen. Companies all over the world are highly vulnerable and lack preparedness for such events because of their low probability and extreme uncertainty (Heckmann et al., 2015). And although local epidemics have been explored and discussed as a possible source of risk in the supply chain risk management literature as a possible source of risk, as they have frequently disrupted supply chains over the previous decades, but a global pandemic such as COVID-19 was completely considered an unlikely event (Hilderink, 2020). This type of disruptions starts small, but grows and spreads rapidly to many geographic areas. Ivanov (2020) states that the COVID-19 pandemic is characterized by the existence of long-term disruption and its unpredictable scaling, the simultaneous spread of the disruption in the supply chain and the virus outbreak propagation in the population, and the simultaneous interruption of supply, demand, and logistics infrastructure.

2.2.2. Impacts of COVID-19 on Construction Industry

The construction industry plays an important role in strengthening the economies and empowering the development of most countries around the world. It provides billions of jobs opportunities for unskilled and skilled workers worldwide and contributes directly and indirectly to the enhancement of economic growth (Dlamini, 2014). COVID-19 has posed serious challenges to the world economy development and

led to unprecedented consequences on the domain of construction (Alsharef et al., 2021). Industrial sectors have been severely disrupted by the pandemic, especially the construction sector (Ogunnusi et al., 2020). Aside from the job risks, labors who perform their work on sites are highly exposed to get infected by the virus from droplet contamination, and no specific and accurate data was available on the risk of infection for workers, which constitutes a serious problem for the construction industry (Zheng et al., 2020).

The passive progress of the construction sector in the COVID-19 crisis has attracted the attention of parties and stakeholders such as contractors, builders, engineers and owners, who faced the situation at a global level (Ogunnusi et al., 2020). Restrictions on construction projects have slowed economic growth, increased unemployment, magnified the loss of investment, and disrupted the supply chain for construction materials (Bsisu, 2020). According to Global Data (2020), the international construction growth has fallen from 3.1% to 0.5% during the year 2020. Also, the Architecture Billings Index (ABI) indicated that the architecture billings have been severely affected during the time of the outbreak, and showed a sharp decrease in those billings after the significant delays in many constructions projects (Zevin, 2020). For the past two decades, AIA has been collecting data from architectural companies' executives and leaders, and producing monthly reports on ABI that construction and engineering companies can take into account in order to forecast the market. The ABI benchmark score is 50, and any higher score marks a rise in billings, whereas scores below 50 indicate a decrease. During March 2020, this score has dropped from 53.4 to 33.3, which was considered the biggest decline for a single month since 25 years. This

score has declined again 3.8 points in April of the same year, hitting the lowest score of all time (AIA, 2020).

At the same time, the Associated General Contractors of America (AGC) has examined the effects of the pandemic on construction jobs by conducting surveys, and the results showed that the market has lost around 975,000 jobs in April only, the number which constitutes about 13% of the construction industry's employment (AGC, 2020). The association kept on tracking the employment status in the construction industry, and releasing reports detailing the jobs recovery. According to a survey released by AGC in November 2020, an additional 85,000 construction jobs have been created in the United States. But the association also warned that the construction industry's employment market might contract if projects continue to be canceled or postponed, and 75% of the contractors who participated in the survey said they had already experienced it (AGC, 2020).

As a result of the pandemic, and like other countries, the United States has experienced enormous disturbances in the progress of almost all construction projects. The construction industry in the US is considered one of the largest industries in the country, with annual spending of over $ 1.3 trillion (Alkhalouf, 2020). Construction work was considered essential in most states, but some construction projects weren't allowed to continue operating. In many states, schooling, healthcare, transportation and utility construction projects were exempt from the shutdown orders as they were considered essential businesses. In some other states, all construction projects were allowed to continue, whereas, in the state of Pennsylvania, no construction project was permitted to remain operating (Construction Dive, 2020). Figure 2 shows a map of the

United States that demonstrates the state guidance on construction projects shutdown for each state.

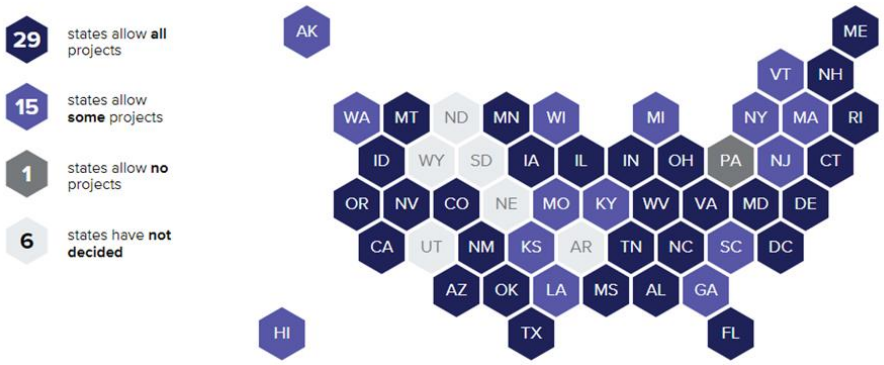

Figure 2: State Guidance on Construction Projects Shutdown (Construction Dive, 2020)

2.2.3. Shortages or Constrained Availability of Labor

In order to contain the pandemic, most governments all over the world have imposed strict measures such as lockdowns and self-isolation, resulting in shortages of labor and personnel whether on-site, in the production factories or at the terminals (Ogunnusi et al., 2020). Many workers have been relocated to their home offices and asked to work remotely after the curfews and quarantine orders. Many others have contracted the virus and had to isolate themselves for long periods of time to recover before they come return to their work place (DBS Group, 2020). According to a study that was conducted in October 2020 (see figure 3), the construction industry was deemed to be with the highest COVID-19 rate compared to other industries (Bousquin, 2020).

Many workers suffered from anxiety and thus preferred not to work in places where they felt vulnerable to attract the virus. The symptoms of depression and anxiety impacted more than 47% of essential labor and personnel in Brazil and Spain during the

pandemic (Brandini De Boni et al., 2020). All this led to disruptions to field crews and shortages of workers on construction sites, in the production factories and at the port terminals. In many cases, the consequences of such disturbances in the human resources has led to temporary shutdowns of several projects. In Maryland, the construction of Marriott International world headquarters and hotel project was ceased after two workers had tested positive (Hull, 2020). This was not the only project that experienced stoppage and delays after workers tested positive for COVID-19, as more than six construction projects in Montgomery County alone have been temporary halted due to the same reason (Lewis, 2020).

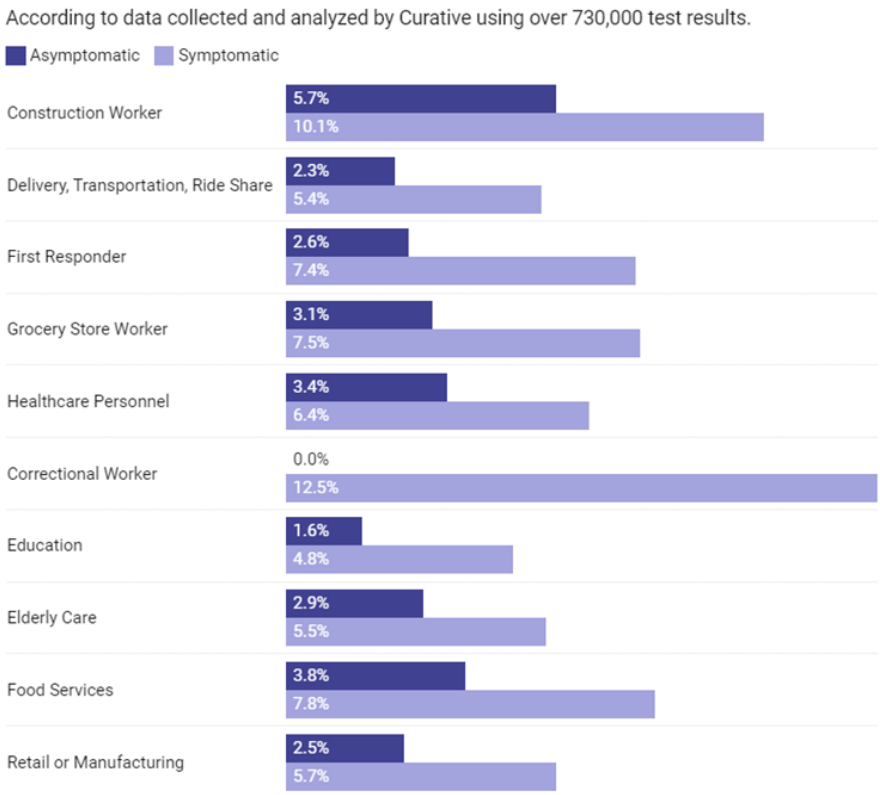

Figure 3: Positive COVID-19 Test Results by Profession (Bousquin, 2020)

Moreover, labors and staff who remained operating during these times had to abide by the new guidelines and safety measures that were imposed by health officials,

which led to further losses in productivity. These recommendations or guidelines include the social distancing for example, which is six feet as recommended by CDC, the obligation to wear face masks, staggered work shifts, sanitization of tools and equipment, and the limitations and restriction imposed on sharing them (Rygiel-Boyd, 2020). Also, gatherings involving large number of people were prohibited to reduce contact between workers. In addition to the prevention of visitors from visiting the sites, and holding training sessions to train employees about the new health guidelines and responsibilities.

2.2.4. Shipping Restrictions and Disruptions

Construction projects highly depend on imports to secure their building materials. In 2018, China contributed for approximately 28% of the world's production, accounting for about $4 trillion. The pandemic has invaded major Chinese companies and businesses, causing adverse impacts on China's production and distribution industries. The hardest-hit states in China accounted for about 90% of all the country’s business. It is estimated that over 5 million companies rely on suppliers that are located in one of the hardest hit regions in China (GEP, 2020). For example, Canada imports more than $48.5 billion from China every year, where about $500 million each of machinery, prefabricated buildings, electronics and electrical components, glass, plastic, steel and iron. In the United States, about 30% of the construction materials, and up to 80% in some cases, are imported from China, and another 20% come from Mexico and Canada. Builders strongly rely on the Chinese imports and they look to China for almost everything related to steel, stone, millwork and plumbing fixtures (Goodman, 2020).

Due to the pandemic and the combined effects of lockdowns, quarantine and border closures, some of the world's largest shipping lines have faced increasing backlogs and delays, stressing the global supply chain and disrupting the world trade (Bragagni and Xhaferraj, 2021). In the United States, an additional lead time from 6 to 8 weeks was evident because of the shipping restrictions. Also, disruption in the supply chain was evident with a 20% average decline in cargo volumes at the American ports during the year 2020 (GEP, 2020). For instance, a 23% drop in shipping containers at the port of Los Angeles was reported in February 2020, after the closure of many plants and manufacturing facilities in China, and the lead time for shipping Chinese goods to the United States exceeded 3 weeks (Assaad and El-adaway, 2021). Moreover, the border between the United States and Canada was blocked to nonessential imports, thus causing difficulties and slowing down the supply of Canadian timber, major component on which the US depends (DBS Group, 2020).

Meanwhile, UK strongly relies on construction materials that are imported from the Far East, such as screws, power tools, fixings, and plumbing fixtures, in addition to timber products mainly from Scandinavia (Kelly, 2020). UK ports have witnessed severe congestions due to the COVID-19-related imports and the strict measures that were imposed, resulting in further disruptions at the terminals. Essential products like medical goods for example were being prioritized over other products and shipments (Salzer, 2020). These disruptions have eventually impacted the unloading times and extended them from one to four weeks (Bingley, 2020).

2.2.5. Transportation and Distribution Constraints

The trucking industry, like other industries, has been severely disrupted during the pandemic, due to the adverse impacts of the lockdowns and curfews, sick truckers and quarantine, and the difficulty of finding a contact point as well. All these combined effects have seriously interrupted the distribution process and led to further delays in delivering the materials to the construction sites (DBS Group, 2020). The wait times at pickup and delivery points have significantly increased due to the shortages of staff and personnel at the sites. Suppliers experienced many transportation and distribution challenges, and materials were kept on loading docks for weeks waiting for trucking companies (Capone, 2020).

According to experts, between March and May, 2020, the commercial transportation activity inside the United States has decreased compared to previous months, as it began operating at an average rate of 83% of the normal rate, and in some regions such as New York and New Jersey, the reduction was more noticeable and the rates reached approximately 66% of the normal (Gatto and Dameon, 2020). Building materials started running six to seven weeks for delivery instead of the typical four weeks (Capone, 2020).

Truck freight slowed down since the early stages of the pandemic. In general, truck drivers were exempt from the non-essential business shutdowns and curfew orders in many countries around the world. They were less motivated to transport goods to hard affected areas, leading to extraordinary price spikes (Salzer, 2020). Many routes turned to be challenging for the drivers because of the restroom and restaurant closures. Moreover, and due to limited space, less-than-truckload (LTL) freight couldn’t be

deposited at the destination terminals after the reported limited space, and thus additional charges were incurred (Gatto and Dameon, 2020).

2.2.6. Shortages or Unavailability of Materials

The shutdown of manufacturing facilities, delays to exports and deliveries, and other issues have led to the unavailability of different construction materials and products (Badman, 2020). Border closures, combined with shipping restrictions, has caused massive delays in the building materials resulting in remarkable shortages (DBS Group, 2020). In addition, the lockdown measures have led to an increased global demand for certain materials and key commodities, causing further shortages, especially after some production factories have resumed the operations and construction has come back online (Hutchins, 2020). For some projects, it may have been possible to stock the required materials on the construction site before they are needed, and thus the impact of the pandemic on their supply chains may have been less. However, this is usually a rare case because the unpredictability of the pandemic prevented most firms from making proper preparations (Alkhalouf, 2020).

Contractors worldwide have expressed concerns about shortages in materials. Most countries around the world have stopped the production of building materials since the early stages of COVID-19, after the strict measures that were imposed (DBS Group, 2020). Between January and February 2020, manufacturing in China was halted due to the lockdown orders causing severe disruptions in the availability of materials worldwide. In the United States, although construction was considered essential in most affected states, many manufacturing plants were deemed non-essential and consequently experienced shutdowns. After the national lockdown that was imposed in

Italy by the Italian Prime Minister in March, 2020, the founder of Le Patner & Associates, a construction law firm in New York, reported shortages in half of the stones that were needed for a certain project, as the stones were sourced from Italy (Diduch, 2020). Also, Toll Brothers, one of the largest home builders in US, experienced shortages in the supply of various material and products, and reported a delay in the delivery of 11 houses in California due to the unavailability of lighting fixtures (Goodman, 2020).

In UK, the availability of imported products in containers was hit by the congestions at the ports due to the lack of personnel (Weinfass, 2020). Also, many of the existing supplies were being diverted to priority projects such as hospitals for example (Bingley,2020). And according to Schünmann (2020), sharp shortages were felt in many materials, especially bricks, plasterboards, doors and steel lintels.

2.2.7. High Prices of Materials

The pandemic and its severe impacts have led to increased prices of building materials. The shipping costs have sharply escalated due to the shipping restrictions and border closures (Bragagni and Xhaferraj, 2021). The shortage of empty containers due to the pandemic has disrupted the international trade, and the cost of transporting goods from China to Europe has approximately quadrupled during the first weeks of 2021, hitting high records. According to shippers, the shipping cost of a 40-foot container from Asia to Northern Europe has jumped from about $2,000 to over $9,000 within three months. The president of the World Shipping council, John Butler, stated that the congestions at the port terminals has led to higher prices, and that extra fees were being

charged because of the long waiting times. The following graph shows how the container freight rates have sharply increased between October 2020 and January 2021.

Figure 4: Container Freight Rates (Freightos Baltic Index, 2021)

The shortages in materials, combined with the increased shipping costs, led to sharp increase in most of building materials costs (Bragagni and Xhaferraj, 2021). Timber prices began escalating since the early stages of the pandemic, hitting a peak level in August 2020. This sharp increase was a result of several reasons, including timber mills closures, distribution problems and rising demand. It was noted that the prices of timber have tripled well above standard inflation (DBS Group, 2020). During the year 2020, and according to the Producer Price Index, softwood lumber has increased by 73%. According to an analysis done by National Association of Home Builders, it was found that the increase in the price of lumber led to an average increase of a single-family home by approximately $16,000 (Bousquin, 2021). Table 5 shows the increase in the prices of steel and lumber.

Hot-rolled coil steel (HRC) prices began rising since September 2020 (Ellis and Trentacosta, 2020), reaching high levels in 2021. Figure 5 shows the sharp increase in

steel prices. In commercial construction, soaring steel prices have led contractors to adjust material costs for their jobs (Bousquin, 2021).

Table 5: Change in Steel and Lumber Prices (Bousquin, 2021)

Material	% change, Dec. 2020 to Jan. 2021	% change Jan. 2020 to Jan. 2021
Fabricated structural metal products	0.5%	3.2%
Iron and steel	8.2%	15.6%
Steel mill products	5.2%	7.4%
Softwood lumber	14%	73%

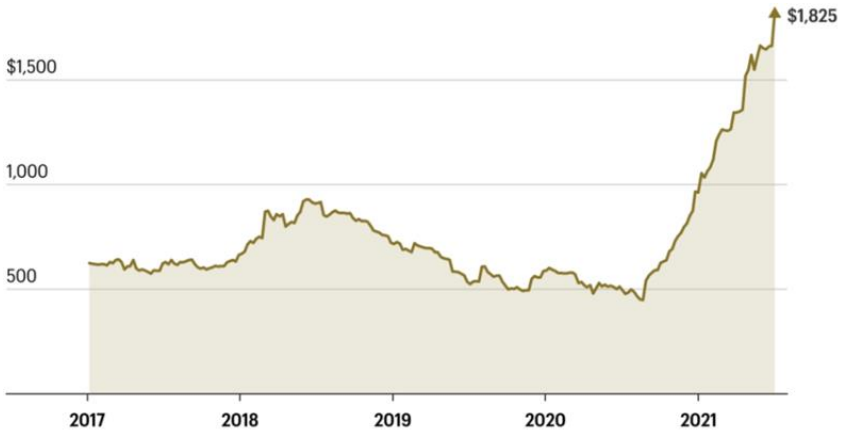

Figure 5: Price of Steel (Lambert, 2021)

2.2.8. COVID-19 and Construction Contracts

The term ‘Force Majeure’ is commonly used in construction contracts that regulate the relationships between different parties. As a contractual term, it helps in distributing the risk between the parties when a force majeure event occurs. Despite its importance, force majeure clauses are sometimes poorly drafted, which leads to disputes and conflicts between the parties. In addition, pandemics are not included in all force majeure provisions as a force majeure event (Hansen, 2020). Many researchers have focused on the effect of the pandemic on the construction contracts, and discussed

the force majeure clause. According to Ogunnusi et al. (2020), being an unforeseeable event, COVID-19 is deemed a force majeure occurrence, and thus it affords time extension for the delays, but at the same time, any regulations that rise from the public authorities will affect and override any previous contractual obligations that were stipulated before the occurrence of the pandemic.

Although the 2017 Red Book does not list in a clear way epidemics or global pandemics in the exceptional events clause as an exceptional event, but it is mentioned that this list is not limited to the events stated in it (Hansen, 2020). For instance, Fenwick Elliot (2014), discussed the Ebola pandemic and explained that such event is likely to fall under the natural catastrophe category. Table 6 provides a comparative analysis of exceptional event and COVID-19 (Hansen, 2020).

Table 6: Comparative Analysis of Force Majeure and Covid-19 (Hansen, 2020)

Characteristics	Description	As observed in COVID-19 outbreak
Unforeseeable	not reasonably foreseeable by parties when they are entering into the contract	This sudden outbreak appeared in Wuhan, China, which later spread throughout the world on an unprecedented scale
Unavoidable	neither party could prevent the occurrence of the event or circumstance	All sectors including construction were affected by this outbreak. The labor-intensive industry is at a greater risk
Uncontrollable	incapability of contracting parties to control the event and its impact	The development and impact of this outbreak is beyond the control of the contracting parties
Impracticable	the event and its impact have adversely affected the fulfillment of contractual obligations	This outbreak has direct and indirect impacts on the construction industry including disruption to supply chain logistics, delays, suspensions, terminations, and insolvencies
Beyond responsibility	the event is not substantially attributable to a party	It is a global health disease which many countries declared as a national disaster

2.3. Case Studies

Many projects experienced the COVID-19 era and suffered its adverse effects. Some were severely impacted, and others were able to survive with the least consequences possible.

2.3.1. China-Australia Construction Supply Chain

This case study examines the effect of the COVID-19 pandemic on the supply of construction materials from China to Australia, and within Australia as well. The materials that were procured from China were being supplied to certain projects executed by a local residential builder in Melbourne.

The study examines the procurement process during five stages of the pandemic period. The following table demonstrates the period of each stage.

Table 7: Research Timeline (Ndukwe et al., 2021)

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

COVID-19 in China:

After confirming the fact of human-to-human transmission of the virus, Wuhan in China was closed and lockdown measures were put in place on January 23, 2020. After that, travel restrictions and social distancing measures were imposed to prevent the further spread of the virus. After few weeks, residents were gradually being permitted to return back to work, and on March 20, 2020, the resumption rate had reached 90% for large Chinese companies due to the strong efforts of the government.

COVID-19 in Australia:

Australia closed its borders on March 20, 2020 for all non-residents, and social distance restrictions were imposed the next day by the government. Construction and manufacturing remained operating as they were exempted from the shutdown orders of non-essential businesses. However, on August 2, 2020, and after the continuous sharp increase in the number of infections, a disaster state was declared resulting in a limited number of workers in the construction sector and other essential businesses. During this round of restrictions, the directions and limitations on the construction industry were far strict. Building of essential infrastructure projects, along with the services that support such projects remained open for workers and personnel who perform on site, with a maximum of 25% capacity compared to normal operations for large scale construction projects.

Impacts on Supply Chain:

According to China National Building Materials Information Network (2020), a survey of construction materials manufacturers was conducted across 25 Chinese provinces, in which 44% have reported disruptions in raw materials supply; 63% stated that transportation and logistics were blocked; and 9% reported an unaffordable increase in prices. Table 8 shows the impact of COVID-19 on delivery times and shipping costs.

Pre-COVID, the order lead-times for China were reported to be between 2 months and 2.5 months for the stocked-standard products and 3 to 4 months for custom products, with delivery times of 21 days. However, local order lead-times were considered much shorter (between 1 and 2 weeks) and products could be delivered within 2 to 3 days. With the spread of the virus across China, builders in Australia began worrying after the shutdown of the upstream manufacturing facilities as workers

were forced to stay at home abiding by the governmental orders. Delays stated being reported either due to the suspension in manufacturing or because of the delays in shipping. Order lead-times were extended by 0.5 to 1 month and delivery times were increased by 14 days as the Australian Border Force imposed quarantine on vessels departing from China. By the end of February 2020, several states in China had successfully curbed the spread of the virus and resumed the production operations. Order lead-times gradually returned to the 2.5-month pre-COVID period, but delivery times remained at 35 days due to the 14-day quarantine on Chinese ships.

Table 8: Impact of COVID-19 on Deliveries (Ndukwe et al., 2021)

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
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 4–6 weeks; (5) delays for x-ray scans

Once the lockdown was announced in Australia on March 23,2020, the construction industry was deemed essential and continued operating, especially due to the fact that this sector plays a vital role by employing about 10% of the total workforce in Australia (Burke, 2020). The spread of the epidemic in Australia had little impact on order lead-times and delivery times for materials from China, but local delivery times

had slightly increased as companies had to implement COVID-19 safety measures and plans. In the next two months, construction operations and logistics worked well, and only few infections were detected in these sectors.

In August 2020, and during the second COVID-19 wave, more stringent restrictions were imposed, and thus new local challenges have risen as the workforce was reduced to 25% on construction sites. Local deliveries were little affected as suppliers had few other workplaces to supply. On the other hand, and due to the limited number of workers allowed in production facilities, the local order lead-times were extended by two weeks. Due to personnel restrictions, material deliveries were significantly delayed when arriving to the sites. Moreover, customs clearance of imported goods was delayed because of the restrictions on ports. Between March and June 2020, the construction sector in Australia laid off around 46,000 employees, the manufacturing sector lost 40,000 jobs, and about 41,000 other jobs in the transportation sector (Armour et al., 2020).

The second lockdown in Australia had the most serious impact on contractors as many warehouses were shut down or had small number of staff due to very strict restrictions that were imposed. Truck loading rates dropped by 40% due to the shortages of drivers. Australia's freight sector has been reported to be in crisis during that period, where a lot of products coming from China and other origins were piled up in warehouses and container parks. In addition, extra charges were incurred because empty containers couldn’t be returned on time as there wasn’t enough staff to unload them.

Figure 6 shows the cost of shipping a twenty-foot equivalent unit (TEU) container from Shanghai’s port to Australia’s major ports. Shipping costs remained at a constant level of approximately US$940 per TEU until January 23, 2020. Due to the

impact of the pandemic, demand for freight transportation has declined significantly, resulting in transportation costs dropping from a maximum of US$949 to a minimum of US$753 by March 20, 2020. With the declaration of ending the restrictions in China by the Chinese government, manufacturing capacities were retrieved and freight rates started escalating with a 20% jump the following week, and continued increasing to higher rates during the following months.

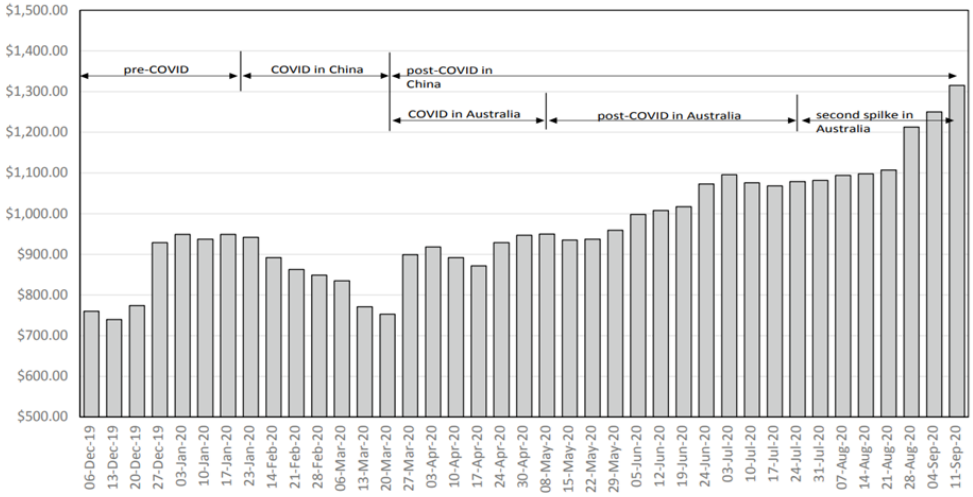

Figure 6: Shipping Costs from China to Australia (China Shipping Network, 2020)

2.3.2. Allegiant Stadium

The Allegiant Stadium is a 65,000-seat stadium constructed in Las Vegas in the United States and costed around $1.97 billion. The work commenced on this project on November 13, 2017, and was completed on July 31, 2020 (Raiders Public Relations, 2020). In just 31 months, Allegiant Stadium is deemed the fastest designed and built football stadium of its size in US. Adopting the Design-Build delivery approach, builders were capable of completing the project on time and within the allocated budget. Early steel mill orders were issued and provided allowing structural steel to start being

constructed on the site on the same day the final permit was obtained. The project teams were able of collaborating and directly sharing BIM contents with the constructor when moving designs between platforms without any missing translations. BIM and a lot of technology were used in the project, such as drones to communicate information, and the badging process so that text messages could be sent to everyone on the job site.

Despite some steel supply chain disruptions, the builders, “Mortenson” and its Joint-Venture partner “McCarthy”, were able to manage the situation and finish on time. The project benefited from the decision that was issued by the governor declaring that the construction works were considered essential despite the measures imposed during the pandemic (Velotta, 2020).

The builders have constantly been sanitizing the work place, especially the congested areas that were being sanitized more than one time each day. They used to provide enough training and PPE, and track everyone entering the site to ensure the implementation of social distancing. The companies additionally staggered the start and end times to decrease the number of staff being available on site at the same time, and utilizing teleconferencing as much as possible. Moreover, a COVID-19 team was created to ensure compliance with the recommendations and laws imposed by the authorities (Velotta, 2020).

Normally, there were around 2000 workers present on site every day. In late May 2020, it was reported that about 31 workers got infected and tested positive for COVID (Slowey, 2020). But the construction work under the management of the JV (Mortenson-McCarthy), has not been delayed despite the increased number of infected workers.

2.3.3. Catalyst Office Building

The Catalyst office building is a five-story building with a total area of 159,000 square-foot, built from approximately 4000 m^3 of mass timber (Bousquin, 2021). The building was opened in Spokane in September 2020, being Washington's only commercial building constructed with cross-laminated timber panels incorporated over a timber structure (Finch, 2020). The use of timber in this project has reduced the need for steel and concrete, and substituted a total of 5,000 tons of carbon, which is equivalent to removing approximately 1,100 cars from the road for one year (Bousquin, 2021).

The project was done by the partnership between "Katerra", an off-site construction company, the Design-Build company "McKinstry", the energy firm "Avista" and "Michael Green Architecture" firm. The goal was achieved through smart building management systems and sustainable MEP design. The mass timber and the cross-laminated timber were locally sourced, and fabricated only 15 miles away from the construction site (Architizer, 2021).

The main philosophy followed during the project was to maximize the efficiency of work, speed up the construction process and reduce the number of workers on-site, by adopting the off-site manufacturing construction. The close collaboration between the design and manufacturing teams had optimized the manufacturing efficiency. Starting from design to on-site installation, every step was well coordinated through a vertically integrated team. The on-site fabrication was extremely minimized. The cross-laminated timber panels entered the construction site fully prefabricated. Eventually, the whole structure was constructed in about 11 weeks (WoodWorks, 2020).

CHAPTER 3

CORRELATION AND CAUSATION OF THE IMPACTS OF COVID-19 ON CONSTRUCTION SUPPLY CHAIN

3.1. Preamble

The literature manifests how the construction sector has been significantly impacted by COVID-19, especially the supply chain and procurement process. The impact was noticeable since the early outbreak stages, propagating gradually through different levels and components of the supply chain. In this section, the effects of COVID on construction supply chain are sorted into three consecutive levels; imposed measures and direct effects, disruptions in the supply chain components, and resulting consequences on materials. The impacts are interrelated, causing eventually further disruptions and problems to the procurement process of construction materials.

3.2. Level 1 Impacts: Imposed Measures and Direct Effects

Since its early stages, the pandemic has introduced direct changes and restrictions into the world. It was the first time that the world has witnessed strict curfews, closure of borders between countries, and such rapid expansion of a virus between human beings. These direct effects or mitigation measures; lockdowns and curfews, sick labor and self isolation, new safety measures and guidelines, border closures and shipping restrictions, are considered the first and main cause behind the disruption of the global supply chain of building materials. They are called the “Level 1 Impacts” of the pandemic and represented in figure 7.

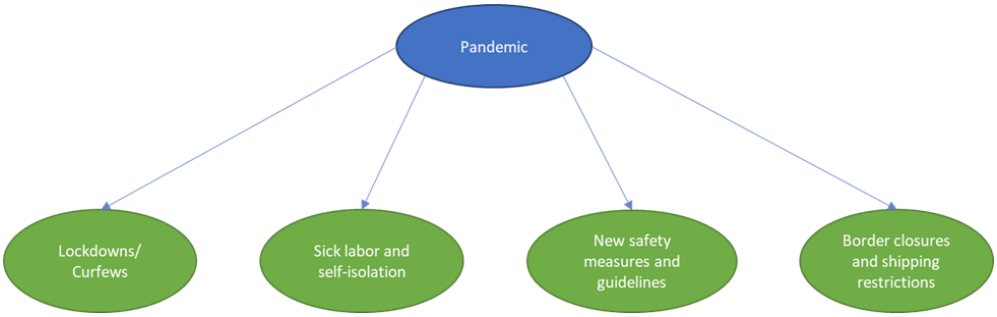

Figure 7: Level 1 Impacts of the Pandemic

Lockdowns/Curfews: The rapid and wide spread of the virus was met with emergency and stringent measures by most governments around the world. The first and common measure was to put the world under lockdown, and to impose curfews to restrict the movement of citizens and thus mitigate the possibility of transmitting the virus. The lockdown was first introduced in China and particularly in Wuhan, the source of the pandemic. The Chinese government declared the state of emergency and imposed the lockdown measures in Wuhan on January 23, 2020, after confirming the human-to-human transmission of COVID. Other provinces in China began gradually forcing the shutdown orders as the virus was spreading enormously. Then, throughout 2020, lockdowns started to be implemented all around the world as the pandemic was transmitted from country to another. Australia confirmed the first case on 25 January 2020, in Victoria, after a citizen returning from Wuhan was tested positive. In March 2020, and after several cases were being identified, the Australian government declared the shutdown protocol within its states (Burke, 2020). All services that were deemed non-essential had to stop operating, and thus the decision didn't include businesses such as construction and manufacturing, as they were exempt from the shutdown orders. In Europe, and on 9 March 2020, Italy was the first European country to issue a nationwide lockdown, with the closure of universities, schools and other non-essential

businesses. After a short time, this state was implemented by other countries like Spain, France, Germany and UK. In Spain for instance, a state of emergency was declared on March 14, and all workers of all businesses were forced to stay at home until April 11. After that, construction workers were allowed to return to work, despite the restrictions (Deutsche Welle, 2020). The lockdown was very strict, enforced by police and military personnel. In US, and due to the rapid outbreak, most state governments have placed the curfews and stay at home orders as a way to contain the spread of the virus between people. The first order was imposed in the state of California on 19 March 2020. Gradually, other states began implementing the lockdown orders. Although construction and manufacturing were considered essential in many states, some projects were not allowed to proceed and had to comply with the shutdown measures.

Sick Labor and self-isolation: The first COVID-19 case was reported in Wuhan, China, on December 31, 2019. As of April 2020, the number of confirmed cases has exceeded 500 million worldwide, with more than 6 million reported deaths. The workforce in construction industry was considerably affected due to the large number of workers who should be present on site at the same time, working close to each other in most of the tasks and activities. This fact has led to increased infections among construction workers when compared to other personnel in other businesses. A study was conducted in Los Angeles between August and October 2020, where 730,000 people from different professions were tested for COVID, reported that construction is deemed the occupation with highest rates of positivity (Bousquin, 2020). In December 2020, reports confirmed that 300 out of 400 workers at Tianjin Electric Power Construction Company project in Serbia tested positive (Everington, 2020). Moreover, and according to research from UT Austin's COVID-19 Modeling Consortium,

construction workers were more likely to have severe outcomes and end up in hospital when they got infected (Buchele, 2020). The increased risk of infection among the construction profession came from fact that large number of workers usually work together or close to each other on construction sites, facilitating the spread of the virus. Eventually, infected workers had to stay at home and isolate themselves until recovery. In some cases, the infected worker was able to return back to work after several days have passed without symptoms, however a negative test for COVID-19 was mandatory in other cases.

New safety measures and guidelines: In the face of the pandemic and the lack of effective treatments, authorities around the world have developed various mitigation methods and strategies to restrict the propagation of COVID-19. Therefore, to limit the infection, WHO recommended reducing contact between infected and uninfected individuals, early detection of cases and early isolation, and common individual and collective hygiene measures. Such measures involve the use of face masks, hand wash, physical distance, and crowded area avoidance. On construction sites, additional guidelines and directions were implemented to mitigate the spread of the virus between workers. Those guidelines include:

- Reducing the number of workers on site
- 6-feet social distance as recommended by CDC
- Separation of employees inside engineering and consulting firms
- Prohibiting gatherings of groups of people
- Staggering work shifts by hours or days
- Compulsory wearing of masks
- Prevention of non-essential visitors from entering the sites

- Frequent screening of body temperatures for workers
- Limitations on sharing tools and equipment
- Continuous sanitization of the area and equipment

All workers and employees had to comply with the health measures and guidelines. In some cases, it was required to hire training staff in order to provide the necessary training and guidance to ensure the adherence of workers to the new health guidelines, and hence to adjust their responsibilities and tasks accordingly.

Border closures and shipping restrictions: The pandemic has directly impacted the terminals of most countries, leading to the closure of many of them and restricting import/export operations. As in the case study of China-Australia supply chain, delivery times from China to Australia were extended by 14 days due to the quarantine on vessels that was imposed by the Australian Border Force (Ndukwe et al., 2021). Also, the third busiest port in the world, Ningbo-Zhoushan in China, was again shut down in August 2020, when one worker only was tested positive by COVID (Tan, 2020). In Europe, the effects were significantly manifested with a 46% cancellation of ship departures on Asia-to-Europe route over a period of four weeks in February 2020, and according to estimates, container ships that were lying idle during this month exceeded the number that was reported during the global financial crisis in 2008 (Saul, 2020). Moving to U.S., container shipping companies had cancelled more than 1,000 scheduled sailings during the first six months of 2020. The three largest alliances of container shipping in U.S., THE Alliance, Ocean Alliance, and 2M Alliance had cancelled around 126 voyages between Asia and North America during the month of August 2020 (U.S. International Trade Commission, 2020).

3.3. Level 2 Impacts: Disruptions in the Supply Chain Components

The direct effects of the pandemic, combined with the strict containment measures that were imposed by authorities and governments, have propagated into the components of the supply chain of construction materials and disrupted their normal flow. Different aspects of the supply chain were interrupted; the workforce, manufacturing process, shipping and transportation operations, and the demand as well.

Shortages or constrained availability of labor: The massive number of infected workers has considerably impacted construction and its supply chain, especially that the construction industry is highly reliable on human resources. Any worker who tested positive for COVID had to stay isolated until recovery. Many others preferred not to work in crowded environments and thus abided by the stay-at-home orders to protect themselves. This has led to significant shortages in labor and field crews. The impact was evidently felt at different stages; on construction sites, in the manufacturing facilities and plants, at the port terminals and within the transportation and distribution companies. In addition, the new instructions and safety measures that were imposed by health authorities have restricted the availability of workers at the work place. In order to abide by the new measures, particularly the physical distance guidelines and tool sharing limitations, number of workers and personnel had to be reduced on-site and off-site. In Australia for example, and during the second wave of COVID, the workforce on construction sites was decreased to 25% due to the strict measures that were put in place. As a result, more than 80,000 workers lost their jobs in the construction and manufacturing sectors. Figure 8 shows the reasons behind the disruption in construction workforce.

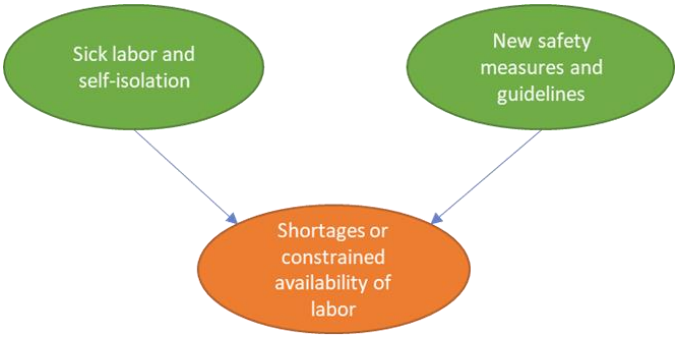

Figure 8: Shortages or Constrained Availability of Labor

Ceasing or disruption in manufacturing: The lockdown measures that emerged in most countries worldwide with the aim of mitigating the spread of the virus have included the manufacturing facilities and production plants. Many factories closed their doors and ceased their operations in compliance with the lockdown orders. Manufacturing in China was suspended during January and February 2020, rising concerns all over the world (DBS Group). In the US, although construction work was deemed essential in several states, many manufacturing facilities were forced to shut down completely. Similarly, in Australia, where many plants halted their operations resulting in 40,000 job losses in the manufacturing sector (Armour et al., 2020). Furthermore, and despite the fact that some plants continued running amid the pandemic, production and manufacturing operations were severely disrupted by the shortages of labor, and the constraints and limitations that were imposed on them while doing their job. This led to considerable reduction in the productivity of plants and factories, causing further disturbances in the supply chain. Figure 9 represents the two direct causes that led to either suspension of manufacturing facilities or disruption in their operations.

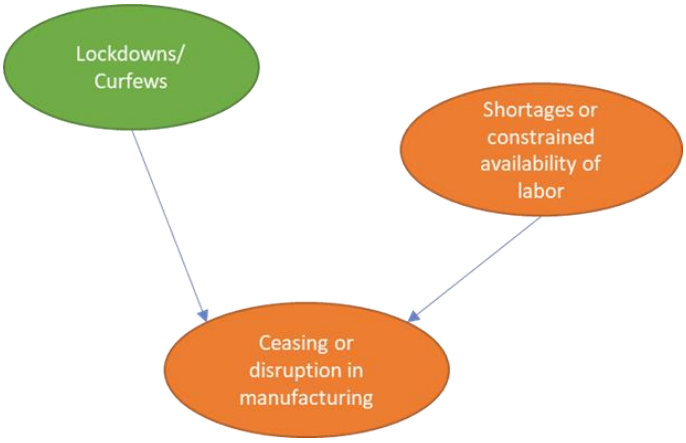

Figure 9: Ceasing or Disruption in Manufacturing

Shipping delays: Border closures and shipping restrictions, combined with the shortages in workforce and disruption in manufacturing, have stressed the global supply chain and caused evident shipping delays of construction materials (see figure 10). Average shipping times were significantly slowed. For example, in 2020, the shipping times from US to China had been 85% longer than in 2019, according to online international freight marketplace Freightos (2020). The shipping restrictions at the US ports added 6 to 8 weeks to the original lead times. Also, shipping times of products coming from China to Australia were elongated by an average of 14 days due to quarantine orders on vessels by the Australian Border Force, and some shipments were delayed by up to one month after the shutdown of factories in China (Ndukwe et al., 2021). Moreover, the lack of workers and personnel at port terminals had increased the loading and unloading times, resulting in congestions and additional delays before the product is being delivered to the construction site (Weinfass, 2020). All these combined factors had hindered the normal shipping process of building materials between upstream and downstream countries.

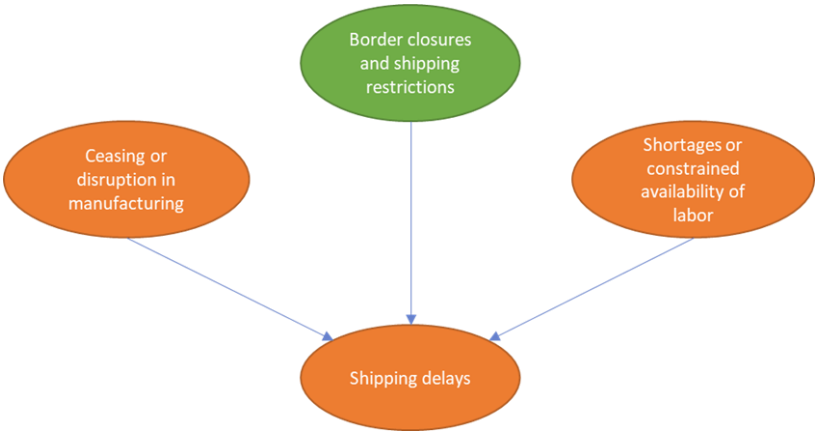

Figure 10: Shipping Delays

Higher shipping costs: The delays that were suffered by the shipping lines have not only resulted in slower delivery times, but also impacted the shipping costs of the materials. The congestions and long waiting times at the ports terminals have led to extra charges on containers and thus increased the shipping costs (Bragagni and Xhaferraj, 2021). A sharp jump in the global shipping costs was witnessed at the end of the year 2020, and then the prices have remained high during 2021. The cost of shipping a 40-foot container from Asia to Europe has increased from $2,000 to $9,000, reached $16,000 from China to U.S., and surpassed $13,000 between Europe and China. In August 2021, the shipping rate has hit $20,000 for the line between U.S. and China, being the all-time high (Freightos, 2021). Also, the case study of China and Australia confirms the increase in shipping costs from a minimum of $740 per container to a maximum of $1,315 (Ndukwe et al., 2021). Therefore, there is a direct relation between shipping delays and shipping costs and it is demonstrated in figure 11.

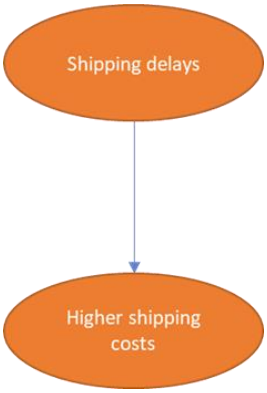

Figure 11: Higher Shipping Costs

Transportation and distribution constraints: The transportation of building materials to construction sites was significantly disrupted during the pandemic period. The lockdown and curfew measures have severely restricted the movement of trucks causing sharp decrease in the transportation and distribution activities in most countries all over the world. Although construction and transportation sectors were exempt from the strict shutdown measures in several areas after considering them as essential businesses, but the impacts were still evident especially in states such as New York and New Jersey (Gatto and Dameon, 2020). Besides, lack of truck drivers and personnel at sites was a big challenge which led to further problems within the delivery process of materials. The loading and unloading times were remarkably extended leaving materials for long time sitting on loading docks waiting for workers to unload (Capone, 2020). Also this was affected by the new guidelines that were implemented, where workers could not collaborate closely and in many cases materials had to be sanitized upon arrival. Thus, all these factors combined have resulted in serious disorders at the level of transporting and delivering materials and products to the sites (see figure 12).

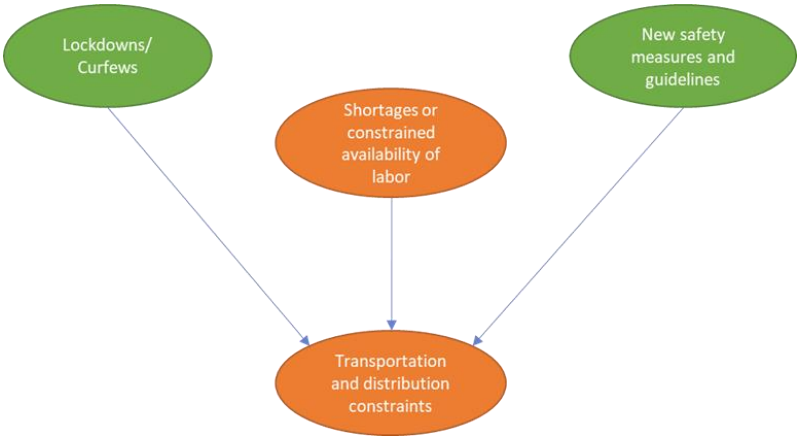

Figure 12: Transportation and Distribution Constraints

Increased demand: During the early stages of COVID, the demand for construction materials decreased due to the lockdown orders. But after a certain time, it was necessary for many projects to resume their activities because of the huge losses that might occur from long stoppage times. This led to a sharp rise in the demand for such materials (Hutchins, 2020). For example, during the summer of 2021 in UK, when builders started rebounding after the national lockdown period, the skyrocketed demand for building products has reached to a point where neither supply was able to catch up, nor contractors were capable of stockpiling stuff for ongoing or coming projects. Hence, there is a direct link between lockdown and demand, which is evinced in figure 13.

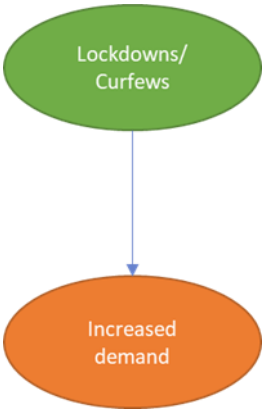

Figure 13: Increased Demand

As shown above, the effects of the pandemic have been manifested in various ways, where level 1 impacts have led to further disruptions on another level. This level is considered the bulk of the construction supply chain. Figure 14 shows a diagram that sums up the “Level 2 Impacts” of COVID-19 on different components, elements and stages of the supply chain.

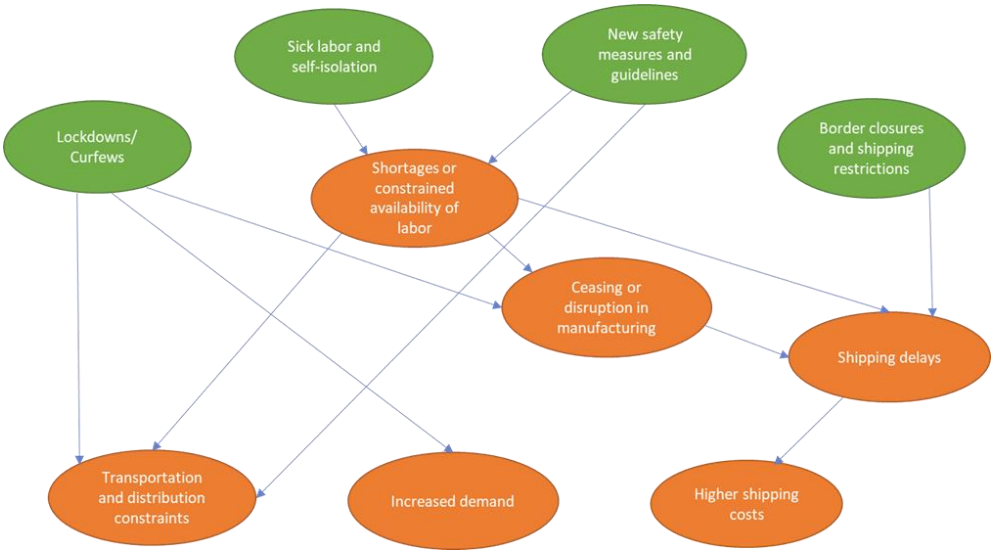

Figure 14: Level 2 Impacts of the Pandemic

3.4. Level 3 Impacts: Resulting Consequences on Materials

After the various disruptions that hit the supply chain at different levels and stages, consequent impacts on materials were severely felt by contractors on construction sites. As a result of the pandemic, materials and products have experienced significant shortages and delays, leaving contractors in an unenviable position. Moreover, the prices of construction materials have been skyrocketing throughout the pandemic period, causing further difficulties and uncertainties about the fate of many projects. This part discusses the consequent effects of COVID-19 on the construction supply chain, which are the materials shortages and increased prices.

Shortages of materials: Many reasons have led to the shortages or unavailability of building materials. One major reason was the shutdown or loss of productivity inside the manufacturing facilities and plants. Once the Chinese government issued lockdown orders, many factories had ceased their production operations, causing reduction in the availability of several construction products all over the world (DBS Group, 2020). Also, the increase in demand for certain materials after construction resumed has further deepened the issue, especially that manufacturing wasn't being fully recovered yet. Another concern was the shipping disruptions and delays, where materials were either stuck at ports or delayed due to certain precautionary measures. For example, about 14 days of delay were evident when products were being shipped from China to Australia during the whole COVID-19 era. And not only shipping, but also the problems while transporting materials into the sites were leading to further delays and shortages. In the United States, about 3 to 4 weeks were added to the typical transportation period of materials from the ports or manufacturing plants to the sites (Capone, 2020). Consequently, lack of materials on sites was an obvious and critical issue. According to the National Association of Homebuilders, about 90% of contractors had reported shortages and delays during 2021, where the most cited material shortages were steel and timber, followed by other supplies such as electrical and mechanical (Smith, 2022). Figure 15 summarizes all the previously discussed reasons that led to shortages in building materials.

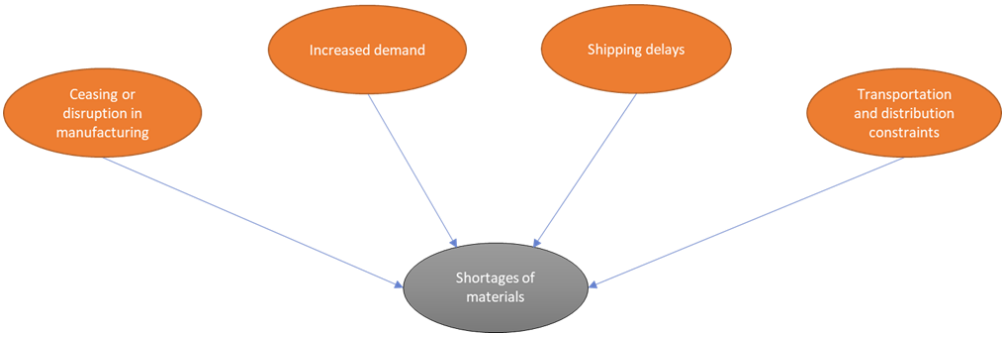

Figure 15: Shortages of Materials

High prices of materials: The prices of building materials have soared after the outbreak began spreading around the world. Some materials have experienced slight increase, however some of them have recorded skyrocketing prices, particularly steel and timber which are deemed two major materials in construction. Various factors led to this increase (see figure 16). The increased demand, combined with the shortages of materials and products, had significantly impacted the prices. And this is a straight-up economics; whenever demand and supply are unbalanced, the price will elevate. Besides, and since the procurement of construction materials usually involves and highly relies on shipping from country to another, from the upstream where products are produced and manufactured to the downstream where the project is being executed, then the increase in shipping costs which is previously discussed, has consequently contributed to the raise of the overall cost of materials (Bragagni and Xhaferraj, 2021). The price of steel has hit an all-time high overpassing $1800 during early 2021, where it was ranging between 500$ and 800$ prior to the pandemic (Lambert, 2021). Similarly, timber was soaring at high levels, trading approximately at 300% above the pre-pandemic price, in addition to the increase in the prices of other materials and products such as concrete, paint, mechanical and electrical products, etc. It was estimated that the cost of a single house was increased by approximately $16,000 according to the

National Association of Home Builders (Bousquin, 2021), which reflects the effect of the escalated prices of materials.

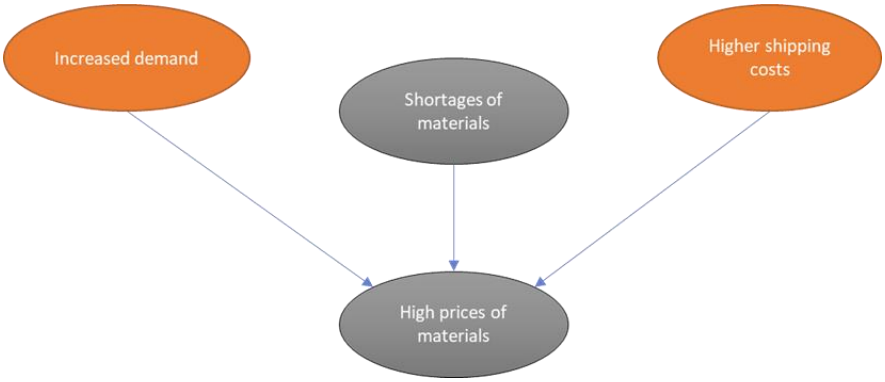

Figure 16: High Prices of Materials

The result of COVID on construction supply chain was eventually manifested in shortages and higher prices of materials. Those two consequences, which are deemed to be the "Level 3 Impacts" of the pandemic on the procurement process, were considerably felt on ground by contractors and project managers. Figure 17 summarizes the relation between the 2nd and 3rd level impacts.

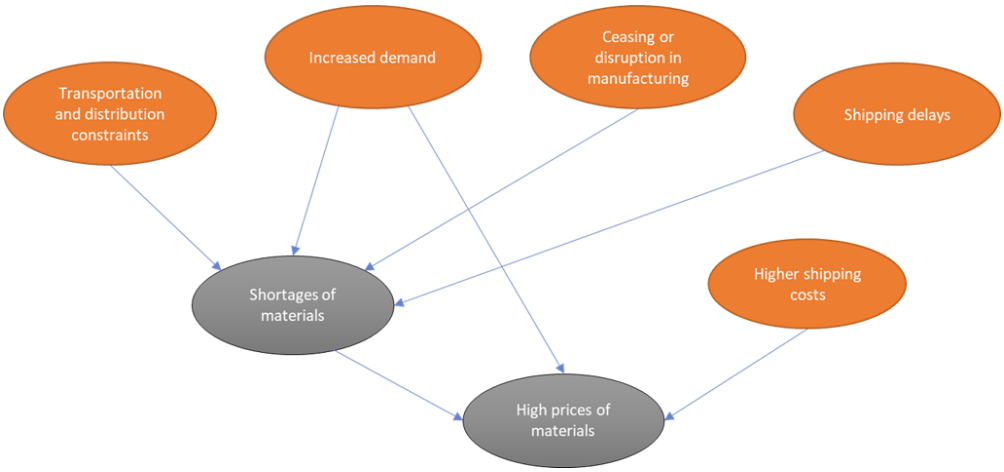

Figure 17: Level 3 Impacts of the Pandemic

3.5. Discussion

This chapter explores the ripple effect of COVID-19 inside the construction supply chain, starting from the primary general impacts, reaching its influence on building materials. After summing up all the relations and causations, an impact diagram is created that summarizes and combines the relationships previously discussed in the chapter (see figure 18). The impacts are classified into three types or levels as referred to above. Level 1 impacts were direct and intuitive, where not only the construction industry was affected, but all industries and sectors as well. The influence of those impacts was the beginning of further disruptions in construction in general and its supply chain in particular. On the 2nd level, workforce, shipping and transportation means, factories and plants, and the demand were all disturbed by the spread of the virus and the orders that were put in place to contain its diffusion. After the disruption of those components, the consequences were evident on building materials, leading to significant shortages and skyrocketing prices. Such impacts fall within the level 3 impacts, manifesting the consequent and ultimate effect of the pandemic on the procurement process. Furthermore, and within the same levels, there are some factors that are interrelated, such as the shortages of labor and the disruptions in manufacturing, or the shortages of materials and their prices, causing exacerbation and additional complexity in the supply chain.

All the effects and consequences discussed previously trigger the procurement process of materials at several stages. This process shall be fragmented and elaborated in order to identify clearly how each stage is impacted.

Figure 18: COVID-19 Impacts on Construction Supply Chain Influence Diagram

CHAPTER 4

CONSTRUCTION MATERIALS PROCUREMENT PROCESSES

4.1. Preamble

The procurement process represents the process of acquiring products and ensures the proper flow of materials from the supplier to the construction site. This process requires proper planning and management in order to obtain a certain quantity of a specific product at the exact time. For that, appropriate supplier should be selected for each product to ensure the needed quality requested by the engineer through the contract documents. The type of supplier, type of product and supply chain mode are all factors that affect the procurement process. Therefore, several procurement scenarios might occur depending on each of those factors. The following sections discuss comprehensively how the construction supply chain is established, how the product is selected and how it is procured under each scenario.

4.2. Product Selection and Approval Process

The first step of any construction project starts by selecting the engineer who is intended to collaborate together with the owner and work on his behalf. Both parties team up to produce the contract documents (plans, specifications, contract conditions, ...). After finalizing the documents, the engineer assists the owner during the tendering process in order to select the general contractor of the project. Then, subcontractors are hired, either based on bids or they are nominated by the owner's team. In some cases, the owner may also nominate the suppliers who should be involved in the project supply chain, otherwise they are chosen based on their quotes for a particular product.

The procurement plan for a certain product begins with the submittals that are submitted by the supplier to the subcontractor, who in his turn forwards them to the general contractor and then to the engineer for his approval. Those submittals are based on the product information that is drafted in the contract documents, particularly plans and specifications. In general, multiple cycles of submission may be required before obtaining the engineer's approval, which is an approval on the product itself. Once obtained, the contractor takes some time to weigh his parameters. As previously stated in the literature (section 2.1.4.), and before taking any decision, he shall study well the ordering and holding costs, and take into consideration the shortage costs as well. Also, the type of product, the storage capacity on site, the location of supplier, the financial condition and the owner's payment policies are all factors that affect the order. For example, the contractor may prefer to order the whole quantity in one batch, or decide to adopt the multiple-batches method. After this time lag, the contractor thereby will have agreed with the supplier on when each batch will end up being fabricated, shipped, and delivered to site, and thus he places the order and starts producing the shop drawings. These shop drawings shall be provided to the supplier and shall contain details about the product to be fabricated, such as the dimensions and measurements. The drawings are reviewed again by the engineer with the possibility of multiple cycles, and upon approval, fabrication can start in the factory. Figure 19 illustrates the whole process that precedes fabrication.

Once the product is ready, it is then shipped and delivered in batches to the construction site, according to the plan that was previously set by the contractor in coordination with the supplier, where different factors are involved in the procurement process.

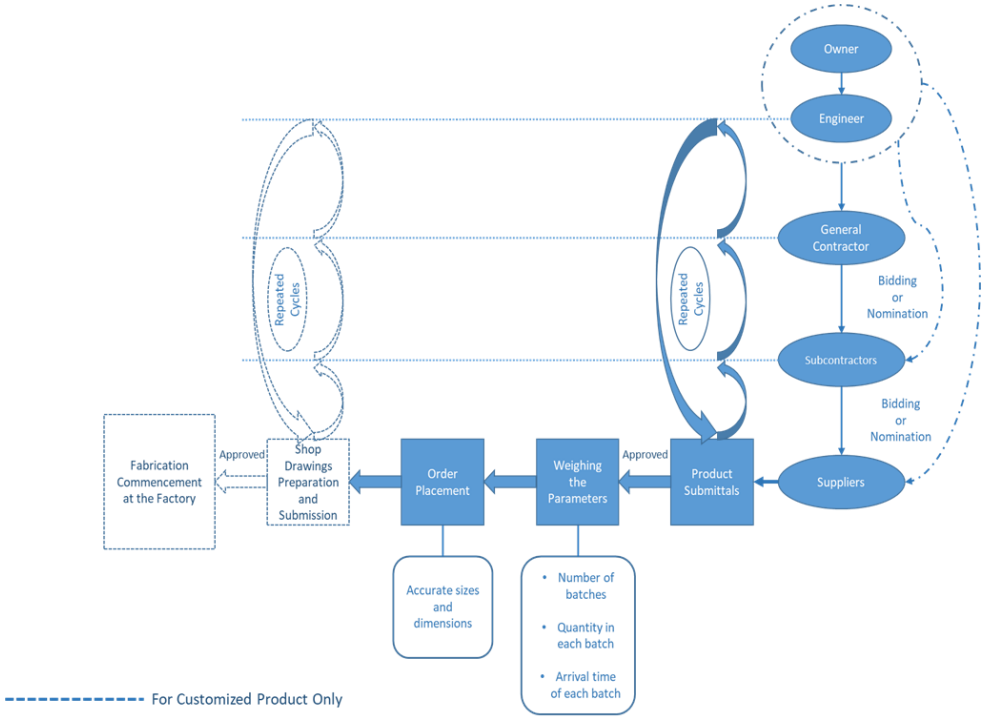

Figure 19: Product Approval Process

4.3. Comparative Analysis of Procurement

The procurement of a particular product is impacted by several factors; location of supplier, type of ordered product, and supply chain mode chosen by the contractor for certain order. In this section, a comparative analysis between domestic and overseas suppliers, stocked and customized products, and between instantaneous, manufacturing and just-in-time modes is conducted in order to identify how the procurement process varies under each factor.

4.3.1. Domestic vs Overseas Supplier

Selecting a supplier is very important when taking into consideration all three aspects of delivering a project; time, cost and quality. In general, time is very critical when considering a far supplier, as shipping will be involved in the process, thus the

probability of delays could be higher during delivery. Also the cost of a certain product is essential, as prices of almost the same product or quality can vary considerably between supplier and another. This is largely attributed to the labor cost where the product is being produced or assemble. Another concern which is the quality of the product itself that should be in compliance with the specifications included in the contract documents by the engineer. Therefore, when choosing a particular supplier for a particular product, especially when it is selected by the contractor, all these parameters should be studied precisely.

A Domestic Supplier is called “domestic” because the delivery of the product supplied by this supplier does not involve transient transportation or shipping, but only transportation by trucks. Such supplier is mainly a local one, or located at a distance that can be handled solely through ground transportation, same as the case of Catalyst Building (section 2.3.3.). In some cases, selecting a domestic supplier can be the best option, especially when the cost of shipping the materials is very high or the preferred time for delivery is short. From the China-Australia case study, the order lead-times from China before the COVID-19 era where between 2 and 2.5 months, however the local order lead-times where only between 1 to 2 weeks. Also during the pandemic period, shipping costs between China and Australia have risen significantly, putting contractors in an uncertain situation before going for Chinese suppliers. Moreover, in general domestic sourcing offers better control over the production of certain product and provides more flexibility over the supply chain and manufacturing processes.

On the other hand, and in many cases, it’s preferable to nominate an Overseas Supplier over a domestic one. An Overseas Supplier comprises transient transportation within the delivery process. Recently, it has been strongly relied on such suppliers in

many projects all over the world. The reason behind this orientation is the wide range and diversity of suppliers who will be available for the contractor, which enables him to secure the desired quality and specifications of the requested product. Some countries are known for their production and supply of specific products, like China and Canada in the production of wood, Italy and Spain in the production of glass, and Germany in that of plumbing materials. In addition to quality, and despite the incurred shipping costs, the production costs can be very economic due to the low workforce cost, thereby resulting in lower overall cost than local supplies. In this scope, China is considered as the world leader, being the biggest exporter of building materials in the world mainly because of its cheap prices.

Therefore, in terms of supplier selection, there are two choices that affect the path of the procurement process, either domestic or overseas. The first saves the stage of transient transportation whereas the second involves such stage. Contractors and even owners should be aware of the advantages and disadvantages of each choice before determining the convenient supplier. Table 9 illustrates the differences between both types of suppliers.

Table 9: Domestic Supplier vs Overseas Supplier

	Domestic Supplier	**Overseas Supplier**
Cost	• Higher production costs • Lower delivery costs	• Lower production costs • Higher delivery costs
Quality	• Better production control • Limitations on quality and specifications	• Better quality • Exact specifications
Lead Time	• Shorter lead time	• Longer lead time
Complexity	• Less Complexity • More flexibility	• More Complexity • Less flexibility

4.3.2. Stocked vs Customized Products

Concerning the type of product ordered by the contractor, this aspect also affects the process of procurement. For example, if the requested product is special designed and customized, then a manufacturing or assembly stage is involved in the process, unlike stocked products that are produced in advance and stored on the shelf of the supplier waiting for orders. Therefore, the lead time for customized products is longer than that for the stocked-standard ones. In the China-Australia case study, it is reported that order lead times before the outbreak were ranging between 2 and 2.5 months for stocked products, however that for custom products were taking up to 4 months in some

cases. Same for local orders where the items that needed manufacturing were taking up to 6 weeks instead of 2 weeks as for the standard ones.

As stated in the literature review, stocked products are produced in advance depending on the historical demand and stored in the supplier's warehouse, unlike fabricated custom products that are built only after the order is received from the contractor due to their special design, and then they are immediately delivered to the construction site. Stocked products usually have low inventory cost and depreciation rate compared to custom products. Table 10 presents a comparison between both types of construction products. The procurement process is longer for a customized product as it requires a fabrication or assembly phase at the plant or factory. Doors, windows, curtain walls and other items that are engineered and designed with particular features and dimensions fall under the category of customized products, in addition to semi-finished items that need certain modifications and assembly. This type of products requires collaboration between suppliers, plants and contractors to ensure the quality and specifications, and it is better for the manufacturer to be involved early in the project.

Table 10: Stocked Product vs Customized Product

Stocked Product	Customized Product
Standard finished products	Configured products
No need for plants	Fabrication at plant is needed
Built in advance based on historical demand	Built once the order is received
Usually stored at supplier's warehouse until receiving the order	Usually immediately delivered to site after being fabricated

Involve collaboration between supplier and contractor	Involve collaboration between supplier, plant and contractor
Low inventory cost	High inventory cost
Low depreciation rate	High depreciation rate
Shorter lead time	Longer lead time

4.3.3. Different Modes of Procurement Models

Selecting the mode through which a certain product will be delivered to the site is a major part of the procurement process. The three modes of construction supply chain are previously discussed in the literature. The instantaneous mode involves the concept of ordering the materials well in advance and storing them in the warehouse before they are being installed. Usually the materials are ordered in several batches, where each batch shall arrive to the site before the complete depletion of the previous one, to ensure continuity in the activities and to avoid any idleness. In general, this mode of supply chain is adopted with overseas suppliers, because of the long lead time that is required to deliver the products to the site, in order to avert unexpected disruptions or delays during the shipping process. And since materials are stored for long times, they often need on-site fabrication and assembly before installation. This mode requires transparency of material inventory in order to identify the available quantities and the quantities that should be ordered.

On the other hand, the just-in-time mode operates under the concept of delivering materials and products at the exact time, shortly before the execution stage. This mode recommends more frequent and smaller sized deliveries to reduce the

quantities that are kept on site before they are being installed, and generally suppliers are chosen based on a certain distance from the site to ensure the exact delivery time. Also, suppliers shall be frequently informed about any modifications in the schedule to alter their delivery times. The arrival time of materials to the site must be in coordination with the preparedness of the cranes and other equipment so that the installation activities can commence immediately. In some cases, a buffer time up to five days might be recommended to avoid unpredictable issues during delivery.

The third mode is the manufacturing mode, where materials are fabricated off-site and then they are delivered to the construction site for installation. This mode has been widely spread since it ensures better productivity and quality of products as they are manufactured in a controlled environment. The Catalyst Office Building had adopted this mode through the off-site company “Katerra”, where timber panels were entering the site fully prefabricated and thus on-site fabrication was significantly minimized. The products that are ordered using this mode are custom products, designed and fabricated according to particular specifications and dimensions that fit the project. The manufacturing mode can be adopted either with the instantaneous or the just-in-time mode. For instance, the manufactured product can be delivered to site and stored in the warehouse, or it can arrive at the exact time just before installation. This mode requires critical logistics and transportation from the factory to the site as the products are usually heavy and bulky, and in such cases contractors prefer the just-in-time strategy. Moreover, manufacturers are better to be involved early when adopting this mode, and the project in general has to be convenient for manufacturing.

Based on the literature and what is stated above, tables 11 and 12 illustrate the characteristics, as well as the advantages and disadvantages of each mode of procurement.

Table 11: Instantaneous vs JIT vs Manufacturing Modes

	Instantaneous	Just-In-Time	Manufacturing
Product	• Usually needs on-site fabrication before installation	• Products are usually of customized type and ready for installation	• Complete or semi-complete components produced in a factory • Manufactured components are sometimes big, bulky and heavy
Supplier	• Either overseas or domestic • Highly recommended for overseas suppliers	• Suppliers are usually selected from an economic circle of a certain transportation distance from site	• Suppliers are selected based on the types of components and their bidding prices
Delivery	• Product usually needs shipment • Product should be delivered to the site before the early start (ES) of the activity is planned to be	• Delivering the right quantities at the exact time • Smaller sized and more frequent deliveries • A time buffer up to five days is desirable depending on the space constraints on-site	• Contractors do not prefer the components to be delivered ahead of the installation schedule • Manufactured components can be delivered using instantaneous or JIT strategies

Requirements	• Project materials should be ordered well in advance • Reordering of materials before reaching the minimum level • Large inventories to be kept on hand • Material inventory transparency is required to identify the available materials and thus the amount that should be ordered	• Developing strategies such as the optimal number of delivery batches, optimal number in each delivery batch and optimal delivery time is necessary • Precise coordination of the timing for delivery and good planning for the availability of the crane for hoisting is required	• Appropriate transportation and logistics from the plant to site is required • Manufacturer to be involved early enough to influence the structural design • The project design must be suitable for manufacturing

Table 12: Advantages and Disadvantages of Procurement Modes

	Advantages	**Disadvantages**
Instantaneous	• Minimum probability for a product to run out of stock • Beneficial in less industrialized countries where poor transportation infrastructure, natural disasters, poor quality control • Protection against production shutdowns • Flexibility of design changes	• Large inventories • Low productivity • Low level of safety • Large amount of waste • Materials may get lost, broken or stolen • High holding costs • More labor and equipment is needed
Just-In-Time	• Reduced inventory • Exact time deliveries • Less waiting time on-site for delivery drivers • On-site resources related to a second handling of components (temporary storage areas, expensive cranes and workers) can be saved	• Risk of running out of stock • Higher transportation cost • Transportation delays due to infrastructure problems, weather, natural disasters or lockdowns

Manufacturing	• Productivity improvement • Quality improvement • Project duration reduction • Reduced storage requirement • Less work load • Low site waste • Safety and environment enhancement • Work is not affected by weather • Low design problems • Improved aesthetic	• Big, bulky and heavy products • Early involvement of the manufacturer • Difficult design changes • Initial design time consuming • Lack of experiences and skilled labor • Risk of production shutdowns

4.4. Procurement Scenarios

The procurement process comprises different stages through which the product will pass before reaching the installation phase. Those stages depend on the factors that are previously discussed in section 4.3. In case of overseas supplier, a transient transportation stage, whether it is air shipping or water shipping, is involved in the process, however this stage is excluded with the domestic supplier. Also, the type of product determines whether manufacturing in the plant is required or not. For the customized products, this stage is included with the adoption of the manufacturing mode of supply chain, whereas for stocked products it is not. And finally, if the contractor, based on his parameters, selects the instantaneous mode over the just-in-time, then warehouse storage operations are involved and followed by in-process inventory just before the installation works. Therefore, and based on these variations and options, different procurement scenarios emerge and thereby define the path of the ordered product.

4.4.1. Domestic Supplier – Stocked Product – Instantaneous Mode

The first scenario starts with a domestic supplier where products are handled and prepared, and because it is domestic, hence no transient transportation is required in the process, but only ground transportation using trucks. And being a stocked standard product, then fabrication and manufacturing at the plant are not involved in this scenario, but since the supply chain mode adopted here is the instantaneous one, thus warehousing and in-process inventory operations are present before installation. Furthermore, the installation phase is associated with on-site fabrication if needed, so that products and materials can fit in place in compliance with the specified positions and dimensions. The following diagram, figure 20, presents the scenario with all the stages involved.

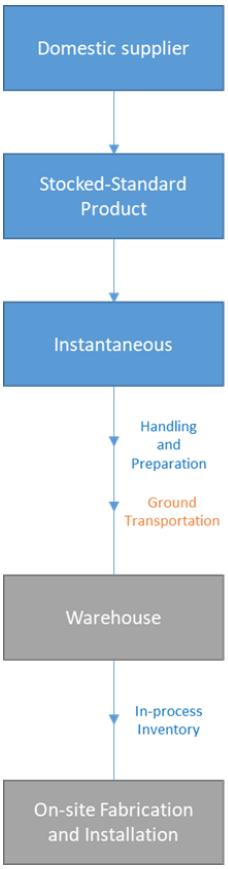

Figure 20: Scenario 1

4.4.2. Domestic Supplier – Stocked Product – JIT Mode

This scenario resembles the previous one regarding the type of supplier and product; both involve a domestic supplier and thus there is no transient transportation, and the product is stocked-standard that does not require manufacturing at the plant. But concerning the procurement mode, this scenario adopts the just-in-time mode. Therefore, the procurement process is exempted from the warehousing and in-process inventory operations. Thus, the process in this case starts with the handling and preparation of the product at the level of supplier, then ground transportation via trucks into the construction site where necessary equipment and human resources should be ready in order to commence with the on-site fabrication and installation activities within a short time. Figure 21 shows the stages included in this scenario.

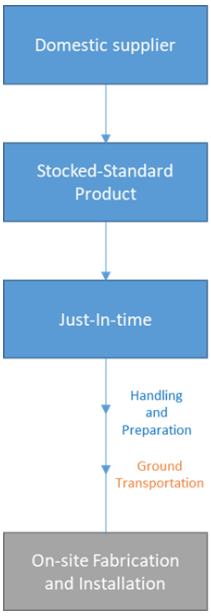

Figure 21: Scenario 2

4.4.3. Domestic Supplier – Custom Product – Instantaneous/Manufacturing Mode

In scenario 3 (see figure 22), the supplier remains domestic, but the type of product is changed from stocked to custom product. So in this case, manufacturing and

assembly at the plant or factory are required in order to obtain this customized product. Thus here the process starts by the typical handling and preparation of a standard product or materials by the supplier, then this product is transported on ground into the plant where it is fabricated and customized in accordance to the specifications. After it is fully fabricated, the custom product is then transported again from the plant to the construction site with coordination between the supplier, plant and contractor. And being a customized product, thus the manufacturing mode of supply chain is utilized here along with the instantaneous mode, thereby the product shall be stored in the warehouse for certain period of time before the in-process inventory, on-site fabrication if needed and installation.

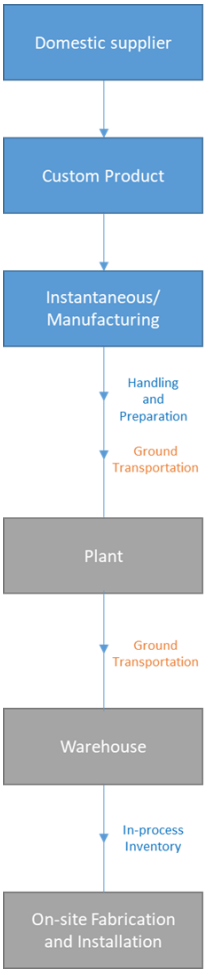

Figure 22: scenario 3

4.4.4. Domestic Supplier – Custom Product – JIT/Manufacturing Mode

This scenario differs from scenario 3 in terms of the procurement mode only, as the adopted mode here is the just-in-time instead of instantaneous, along with the manufacturing mode, as the product is still a customized one. Therefore, warehousing and in-process inventory are excluded from the procurement process. Hence, the process begins with handling and preparation, ground transportation to the plant, manufacturing and assembly, ground transportation to the site where on-site fabrication and installation take place. Figure 23 presents the steps and stages engaged in this scenario.

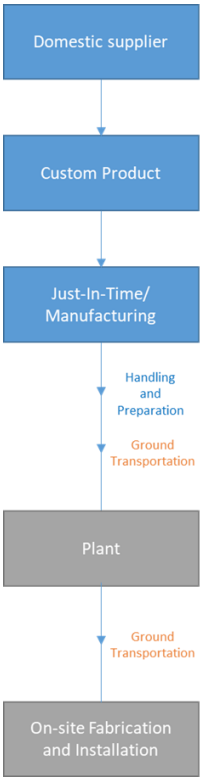

Figure 23: Scenario 4

4.4.5. Overseas Supplier – Stocked Product – Instantaneous Mode

The 5th scenario differs from the previous scenarios regarding the type of supplier. Here the supplier is overseas, which means that the transient transportation or

shipping is now a part of the process. So after the preparation of the product by the supplier, it is transported into the port, then shipped through water or air to the destination port. This transient transportation stage includes the clearance process before transporting the stocked product again by trucks into the warehouse of the subcontractor where it is stored, since the mode adopted in this case is the instantaneous one. Eventually, the product is prepared for fabrication and installation. All stages of this scenario are illustrated in figure 24.

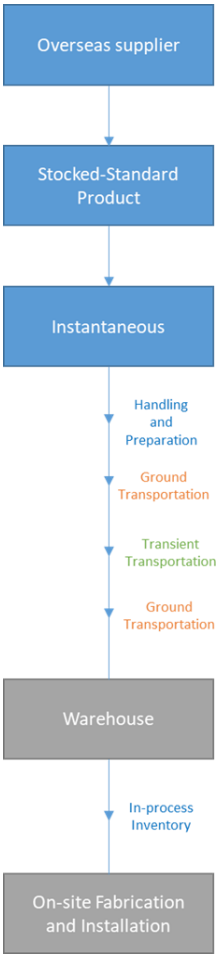

Figure 24: Scenario 5

4.4.6. Overseas Supplier – Custom Product – Instantaneous/Manufacturing Mode

The combination between overseas supplier and custom product can produce two scenarios. Because the product is customized, then the manufacturing stage at the plant is involved, where the plant may be either overseas or domestic. For that, the 6th scenario constitutes of overseas supplier with overseas plant. The product is prepared and transported to the plant at the source country where it is fabricated according to the specs previously approved by the engineer, then it is transported to the port, shipped to the destination country and eventually conveyed by trucks to the construction site. And by adopting the instantaneous mode, the product is kept in the warehouse until installation. However, scenario 7 includes a domestic plant, therefore the standard product is shipped from the country where the supplier is located and then locally customized before it is delivered to the site. Likewise, the custom product is stored at the warehouse due to the instantaneous mode adoption, followed by in-process inventory, on-site fabrication and installation. Both scenarios, 6 and 7, are presented in figures 25 and 26 respectively. For the cases of overseas supplier, the just-in-time mode is excluded due to the long lead time and high probability of delays during shipping and clearance processes, and thus contractors and subcontractors prefer the instantaneous mode in order to stay on the safe side.

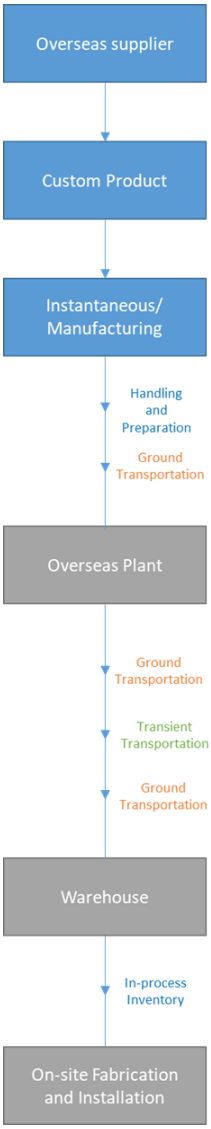

Figure 25: Scenario 6

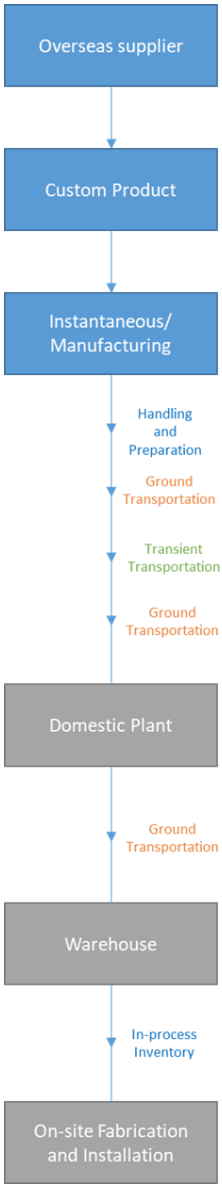

Figure 26: Scenario 7

4.5. Overall Supply Chain Framework

The supply chain of a construction project represents a cycle that starts with the owner or user and ends eventually with the user. This chain involves various stakeholders who are connected with different relations and processes (see figure 27). After selecting the engineer, general contractor, subcontractors and suppliers, the submitting and approval processes take place before the order is placed and delivered to

the site. This delivery process can occur under any of the scenarios previously discussed in section 4.4. Finally, the product is installed and eventually used by the user. This supply chain can be very complex, including a large number of suppliers and therefore involving several scenarios simultaneously.

As shown before, each scenario, which is characterized by specific type of product, supplier and mode, encompasses diverse procurement stages and phases than the other scenarios. Scenarios 6 and 7 for instance, where the supplier is overseas, the product is customized and the supply chain mode is instantaneous/manufacturing, are evident to be the longest and most complicated. Hence, the risk of disruptions is higher for such scenarios compared to others that are shorter and less complex. COVID-19, which has been the major disruption for the past few years, has affected the construction supply chain in various ways. Each stage of the procurement process has been disrupted differently. Thus, in order to identify clearly how the procurement process is impacted by COVID-19, the impacts on each stage of this process should be identified separately. The next chapter studies the effects of the pandemic on materials procurement by mapping the impacts that are discussed in chapter 3 on the procurement scenarios that are established in this chapter.

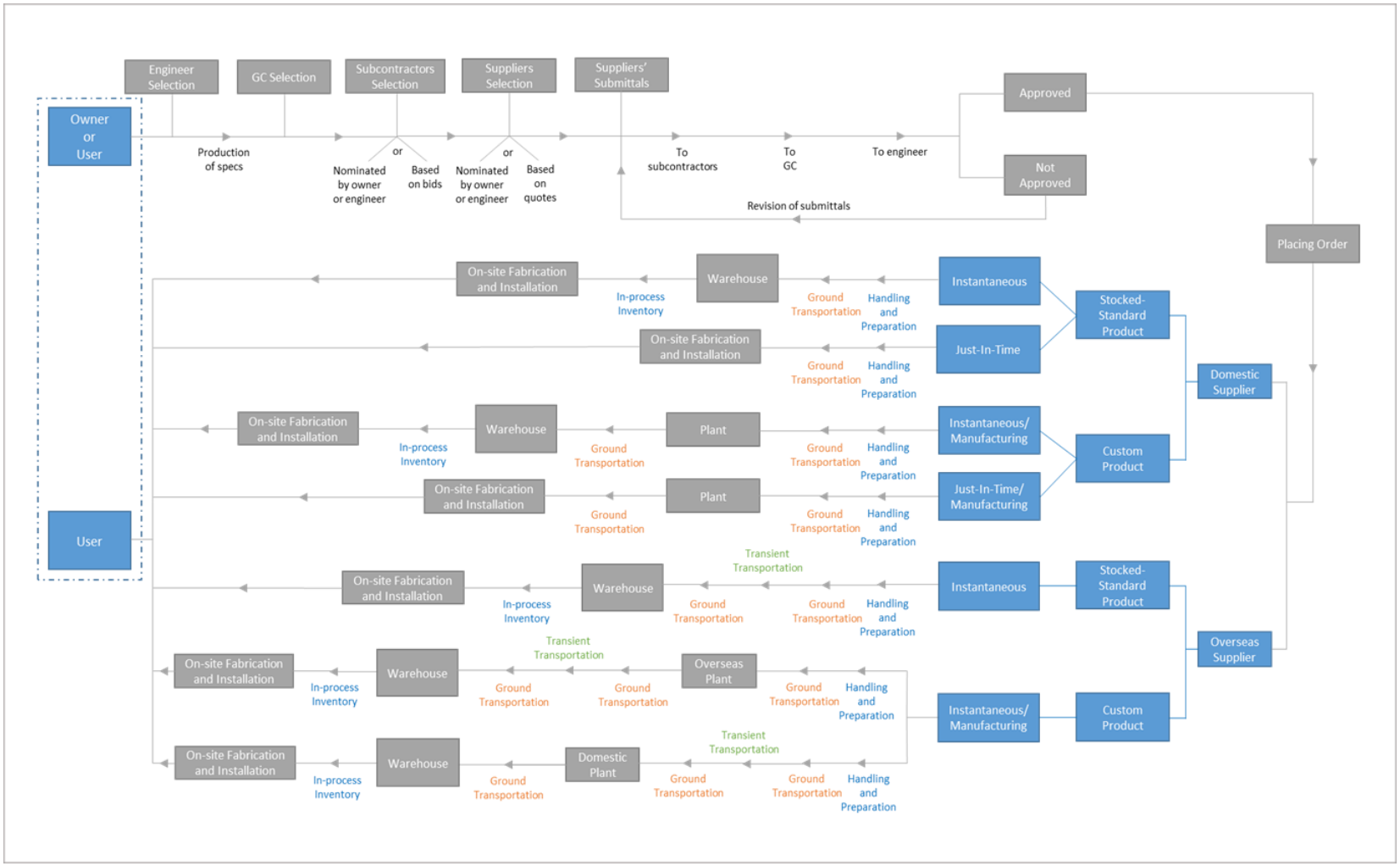

Figure 27: Supply Chain Framework

CHAPTER 5

COVID-IMPACTED CONSTRUCTION PROCUREMENT PROCESS

5.1. Preamble

The scenarios discussed in chapter 4 of this study depicts the stages through which any construction product passes before being executed on site. To identify the disruptions in the procurement process, each of these stages should be examined to determine the way it was affected by COVID-19. Each stage involves particular components, resources and tasks that have been victims of the pandemic. The vast spread and diverse impacts of COVID on the construction industry in general, and its supply chain in particular, have hit all phases and stages of building procurement process, putting projects' stakeholders in uncertain situations during the past years. This chapter will study each procurement stage separately, map the impacts of the pandemic on it, and eventually infer the project management challenges that were experienced by project participants.

5.2. Mapping COVID-19 Impacts

As discussed in chapter 4, any building product passes through several stages before it is installed on site. Each of these stages has been disrupted by the diverse impacts of COVID, that were explored thoroughly in chapter 3. This section will demonstrate precisely how the procurement process has been interrupted or even broken in certain cases, by showing the components of each single stage and hence the reason it was impacted. The stages involve 'handling and preparation', 'ground transportation',

‘transient transportation’, ‘plant operations’, and the process of ‘warehousing, in-process inventory and installation’.

5.2.1. Affected Procurement Stages

Each of the five stages that link the supplier with the end user through the product, comprises specific elements and actions which have been hit by the pandemic.

- **Handling and Preparation:**

This stage represents the first step of the delivery process of materials. Stocked-standard or semi-customized products shall be handled and set in preparation for delivery. This stage takes place at the level of supplier entity itself. Therefore, it is significantly impacted by the imposed lockdown measures as many supply companies had to close and abide by the governmental orders. Thus, internal operations and production facilities were ceased for several periods of time. Also the massive increase in demand for building materials which resulted from lockdown measures, has made the situation even worse for suppliers who weren’t capable of fulfilling all orders and requests. Moreover, this stage was considerably affected by the shortages and constrained availability of labor responsible for the handling process, which is primarily caused either by isolated infected labor or by the new safety measures and guidelines. Figure 28 depicts the impacts pertaining the handling and preparation stage of procurement.

- **Ground Transportation:**

The ground transportation stage through which the product is conveyed by trucks was considerably interrupted during the pandemic, suffering from distribution and movement constraints. Transportation and distribution firms were forced to pause

their works in certain areas where lockdowns and curfews were stringently implemented. Based on China – Australia case study, and according to a survey conducted by China National Building Materials Information Network, 63% of manufacturers over 25 Chinese provinces have claimed disturbances in transportation and logistics. And even in provinces where this business was allowed to continue operating by considering it as an essential business, the fact that it relies on the human resource has left it with insufficient drivers and workers to accomplish the job properly. In Australia, lack of drivers has resulted in 40% drop in truck loading rates (Ndukwe et al., 2021). Besides, workers had to abide by the new guidelines which restricted their performance, especially at the pick-up and drop-off locations. The effects and implications of COVID on the ground transportation stage are represented in figure 29.

Figure 28: Handling and Preparation Related Impacts

Figure 29: Ground Transportation Related Impacts

- **Transient Transportation:**

For the case of overseas supplier, materials have to be conveyed from the origin into the destination country where the project is being executed. This stage is achieved either through sea shipment or by airplanes. It requires personnel and workers at the ports of both countries and within the shipping system. Thus, this mode of transportation was hit by the shortages of personnel and staff during the pandemic period, leaving orders and shipments considerably below the normal flow, with remarkable delays all over the world, especially for shipments originated from the world's biggest exporter China. Also, the disruptions in manufacturing and production operations added up prolonged delays to delivery periods. Many countries had issued instructions ordering full or partial closure of the borders to contain the transmission of the virus from the outer world. These closures and restrictions led to significant delays to materials shipments and frequently resulted in the cancellation of many others. Therefore, shipping delays were manifested as a substantial consequence at this stage on

materials procurement, resulting in escalated shipping costs that were remarkably manifested in the China –Australia case study. Hence, the impacts and consequences associated with this stage are shown in the following figure 30.

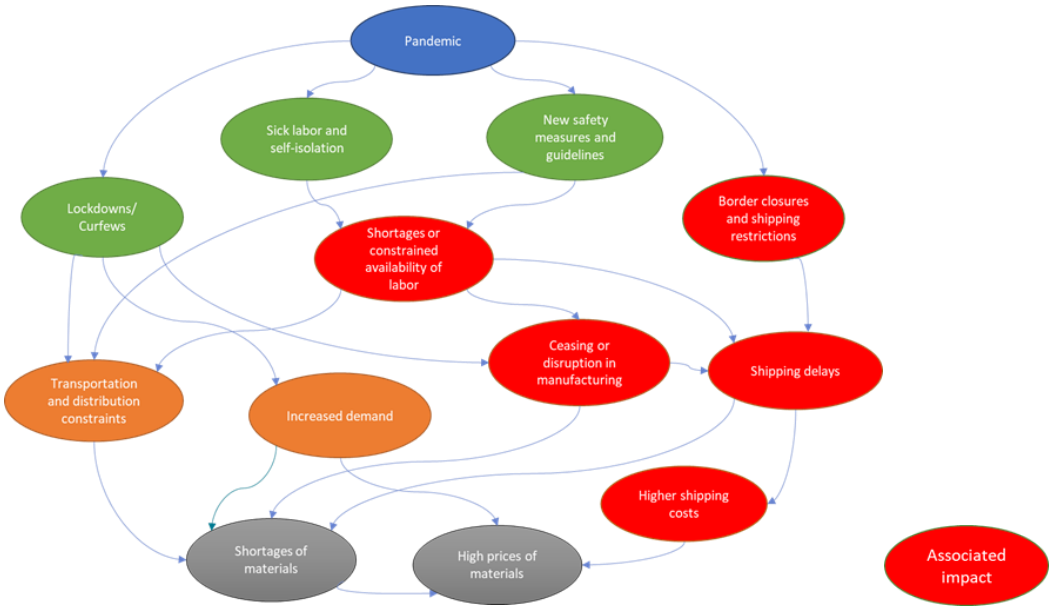

Figure 30: Transient Transportation Related Impacts

- **Plant Operations:**

At this stage of the procurement process, customized products undergo fabrication and assembly at the factories and plants in order to meet the engineer's specifications. During the pandemic, and abiding by the governmental orders and lockdowns, many plants had to shut down and halt their activities until restrictions were lifted. These orders were dependent on each country or state, as some of them were very stringent, unlike other countries in which such businesses were deemed essential and hence they remained running. But even while functioning, the operations were affected by the lack in labor force and the strict regulations and guidelines that were imposed within workplaces, leaving productivity and effectiveness in work under normal levels. All these factors combined have resulted in massive disruptions and breakdowns at

almost all manufacturing facilities and plants. Figure 31 depicts the impacts and implications that were felt at this stage.

Figure 31: Plant Operations Related Impacts

- **Warehousing, In-process Inventory and Installation:**

At this phase, materials will be within the possession of the contractor. In case the adopted mode is instantaneous, then warehousing is involved before installation. Here the influence of COVID is what was felt during the project execution stage. This comprises the lockdown measures where several construction project had paused their activities on site, the shortages in labor and personnel on ground where tasks were delayed and extended, and the new safety measures that were introduced to the new world which decreased the productivity and limited the movement and availability of workers. In addition, and the most significant and ultimate impact of the pandemic on construction supply chain was evident at this stage with the considerable shortages in building materials, along with their escalating prices, which left contractors in

complicated and risky situations. See figure 32 in which the effects and consequences of COVID on this stage are highlighted.

Figure 32: Warehousing, In-process Inventory and Installation Related Impacts

Therefore, each procurement scenario of the scenarios previously discussed in section 4.4, was affected based on the stages that constitutes it. In the following sub-section, the impacts will be projected on each scenario, in order to manifest clearly how the procurement process of construction materials was impacted.

5.2.2. Projection of Impacts on Procurement Scenarios

In this sub-section, the effects of COVID-19 will be mapped to the procurement scenarios discussed in chapter 4., in order to demonstrate the consecutive disruptions at each stage of procurement (see figures 33 to 39).

Scenario 1:

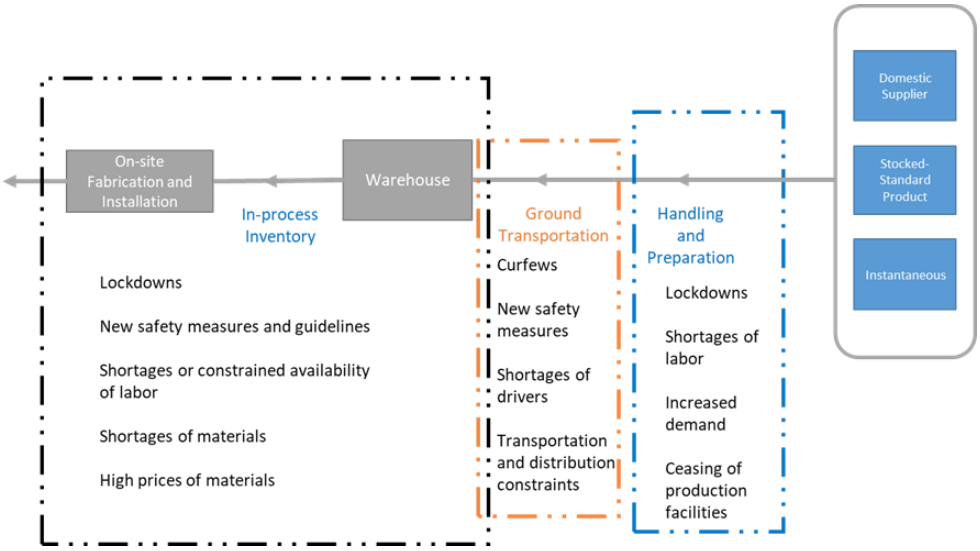

Figure 33: Scenario 1 Projected Impacts

Scenario2:

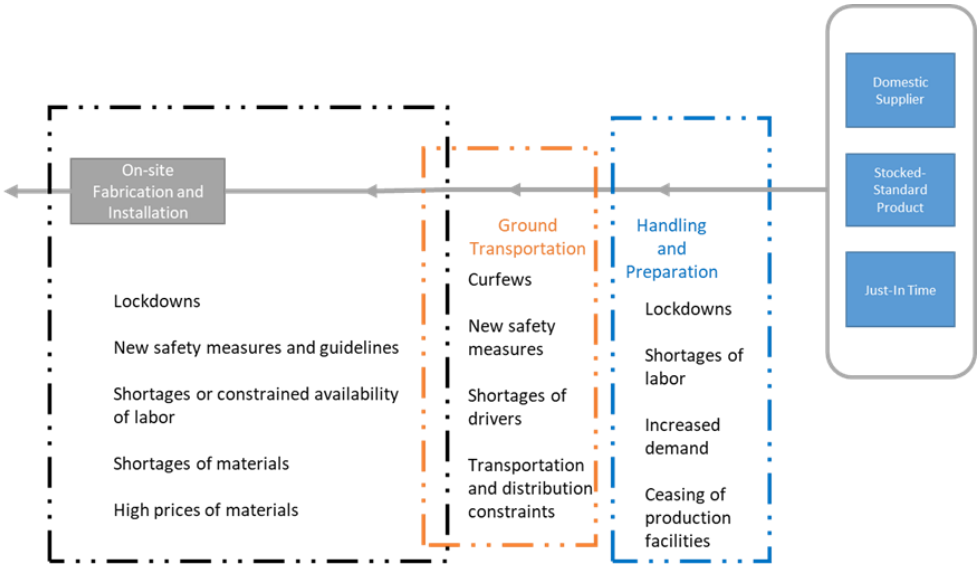

Figure 34: Scenario 2 Projected Impacts

Scenario 3:

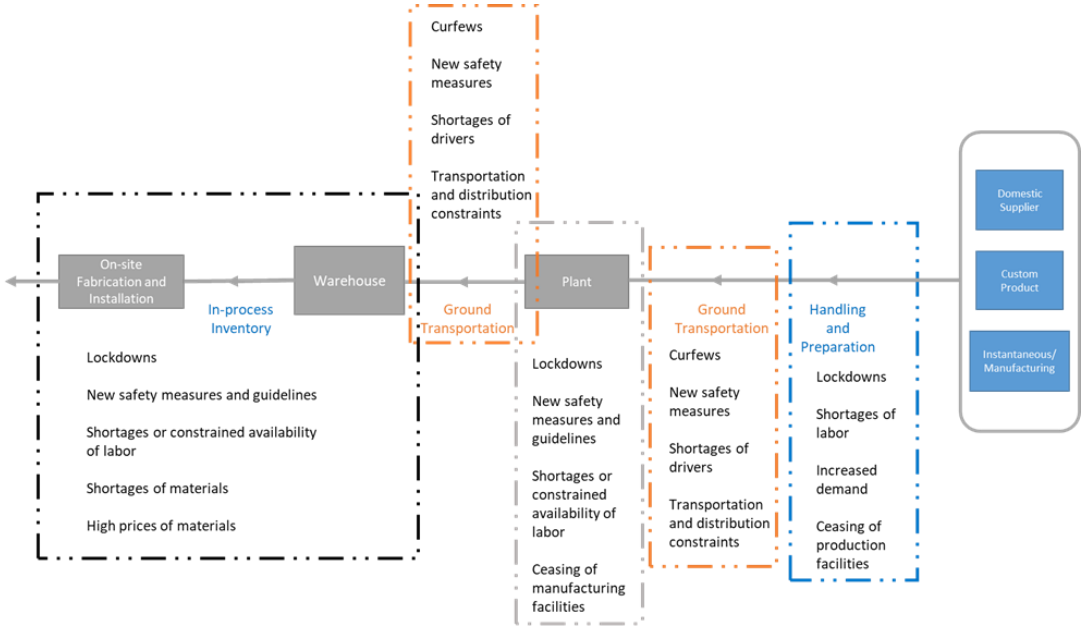

Figure 35: Scenario 3 Projected Impacts

Scenario 4:

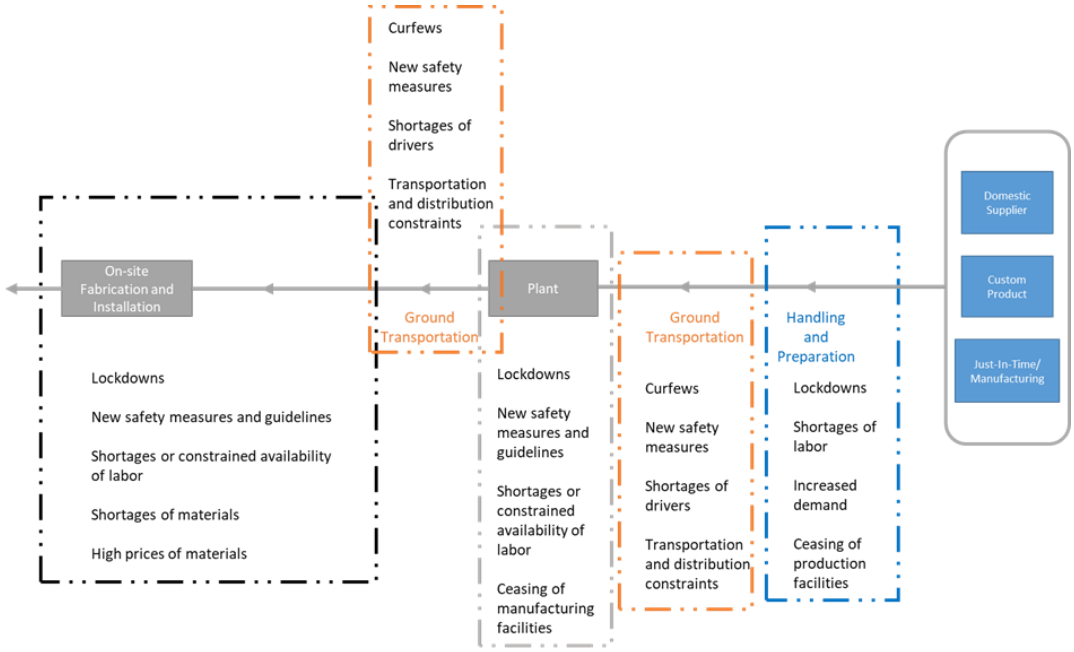

Figure 36: Scenario 4 Projected Impacts

Scenario 5:

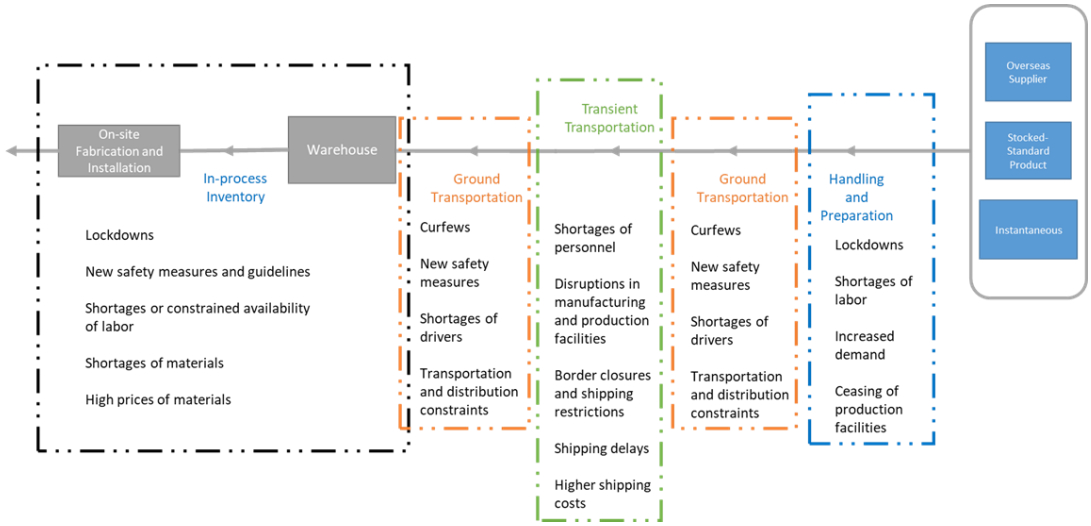

Figure 37: Scenario 5 Projected Impacts

Scenario 6:

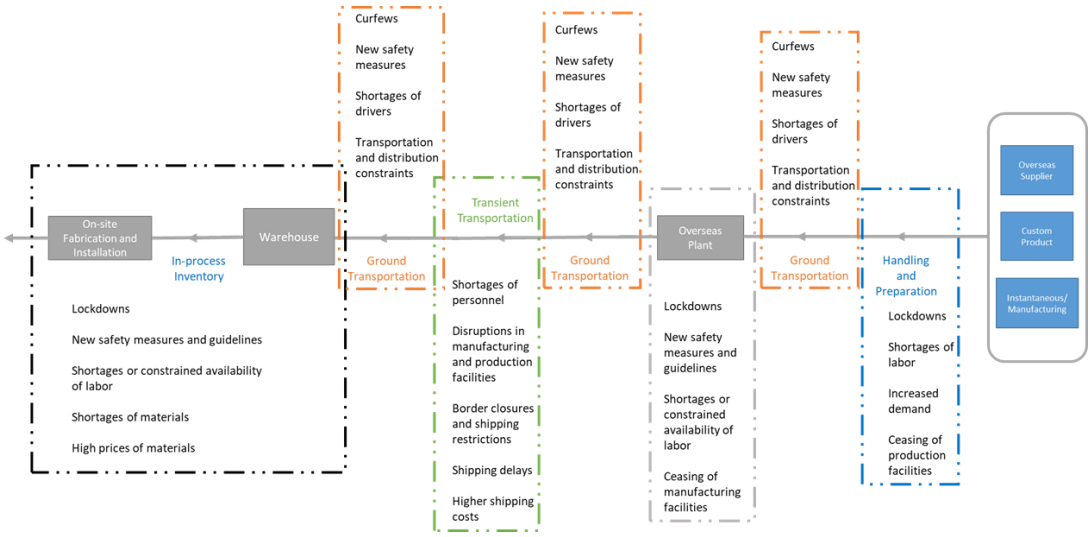

Figure 38: Scenario 6 Projected Impacts

Scenario 7:

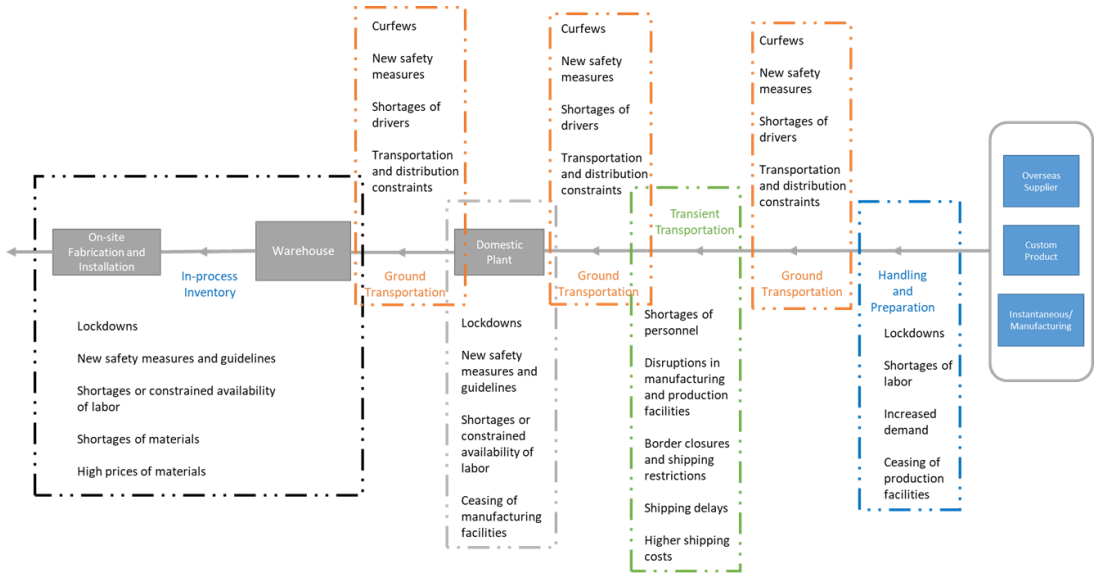

Figure 39: Scenario 6 Projected Impacts

Projecting the impacts on each stage of each procurement scenario emphasizes the severe and inevitable influence of the pandemic on construction supply chain. Depending on the type of product, supplier and adopted delivery mode, the severity and complexity of disruptions vary between scenario and another, generating several project management challenges for project stakeholders.

5.3. Project Management Challenges

Unlike other disruptive events, this event has its action taking over a wide scale. There has been no phase within the procurement process that was not substantially hampered by the impacts of the pandemic. Most of the previous witnessed events, like natural disasters for example, have disrupted confined areas and regions, and for limited periods of time. Thus, either the upstream, the downstream, or specific stages in

between, were being affected. However, in this case, all procurement stages that link the supplier with the end-user are severely disturbed.

Looking at the 7 scenarios, each one involves particular number of stages and each stage is obstructed by specific factors. As the number of stages involved increases, the complexity and risk escalate. Considering scenarios 1, 2, 3 and 4 for instance, all the procurement process is performed locally, thereby minimizing the supply chain phases by eliminating the transient transportation and other prerequisite operations that should be executed overseas, therefore lessening the risk and scale of disruptions on the overall process. Moreover, Scenarios 1 and 2 exclude the manufacturing operations and thereby remain unaffected by the disturbances occurring inside plants and factories. However, scenarios 6 and 7 are deemed the most complicated as they include all procurement stages previously discussed, and hence they are prone to high level of risk.

study, the COVID pandemic has emerged in China and then it was transmitted to Australia. Therefore, 3 phases can be examined case: COVID in China, COVID in China and Australia, and COVID in Australia. Assuming that the adopted mode of supply chain is “Instantaneous”, scenarios 1, 3, 5, 6 and 7 are presented in figures 40 to 44, manifesting the impacted stages during the 3 phases. The stages highlighted in “Red” are the affected ones.

It is evident that the scenarios involving overseas supplier, where the products are delivered from China to Australia, have been always impacted, even when the pandemic was still outside Australia. Delays and increasing shipping costs were significant since the early stages of COVID (Ndukwe et al., 2021). In addition, and when considering scenarios 6 and 7, the delivery of the ordered product might be disrupted at 7 stages before being installed on site. Therefore, as the supply chain

comprises more stages, it becomes longer, more complex, riskier, and more prone to breakdowns and disruptions. This provokes the project management procedure and makes it exceedingly challenging. All stakeholders have found themselves in unenviable and risky situations, particularly contractors, and many claims have been raised since the beginning of COVID-19 era.

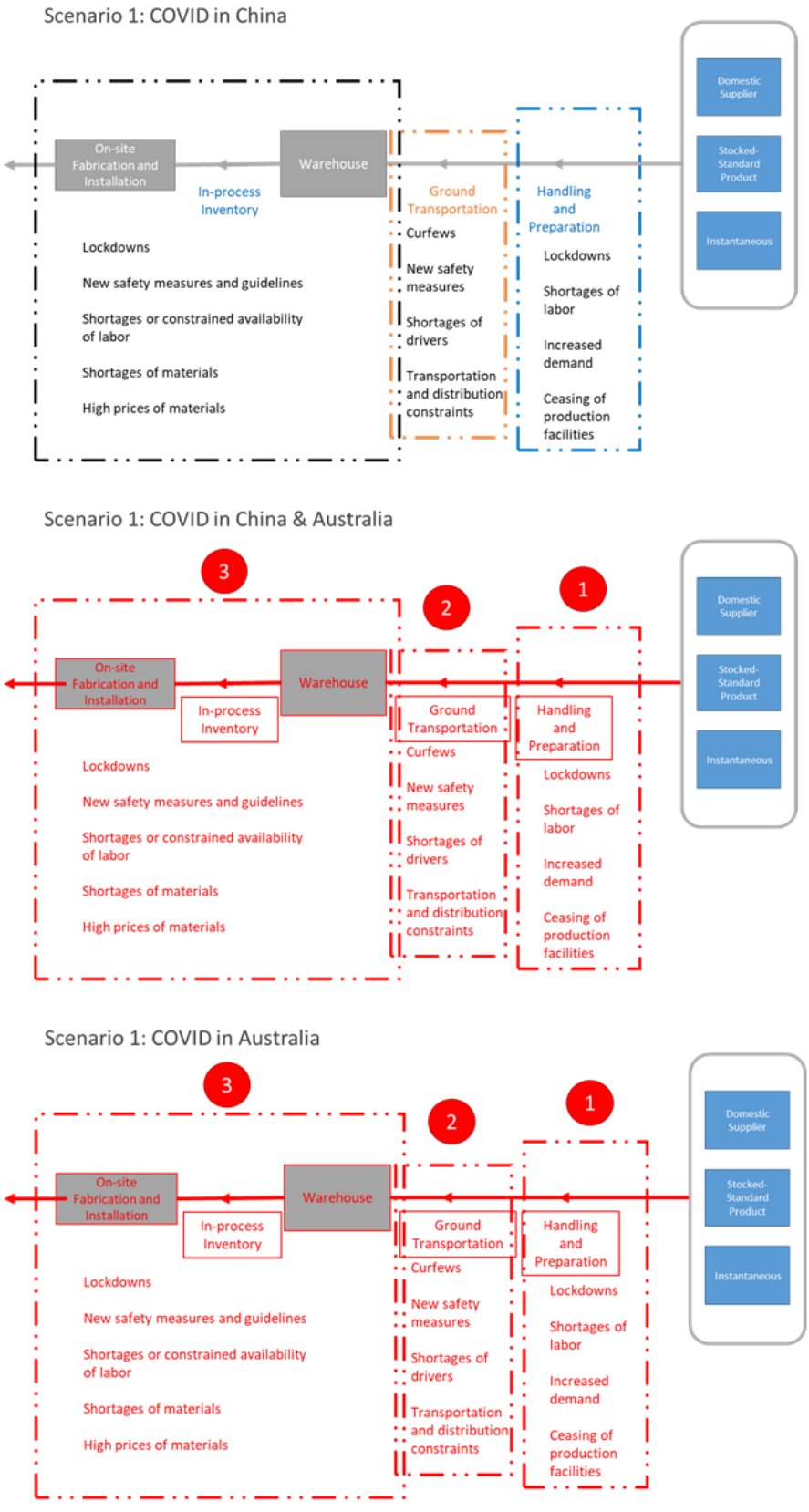

Figure 40: Scenario 1 Impacted Stages

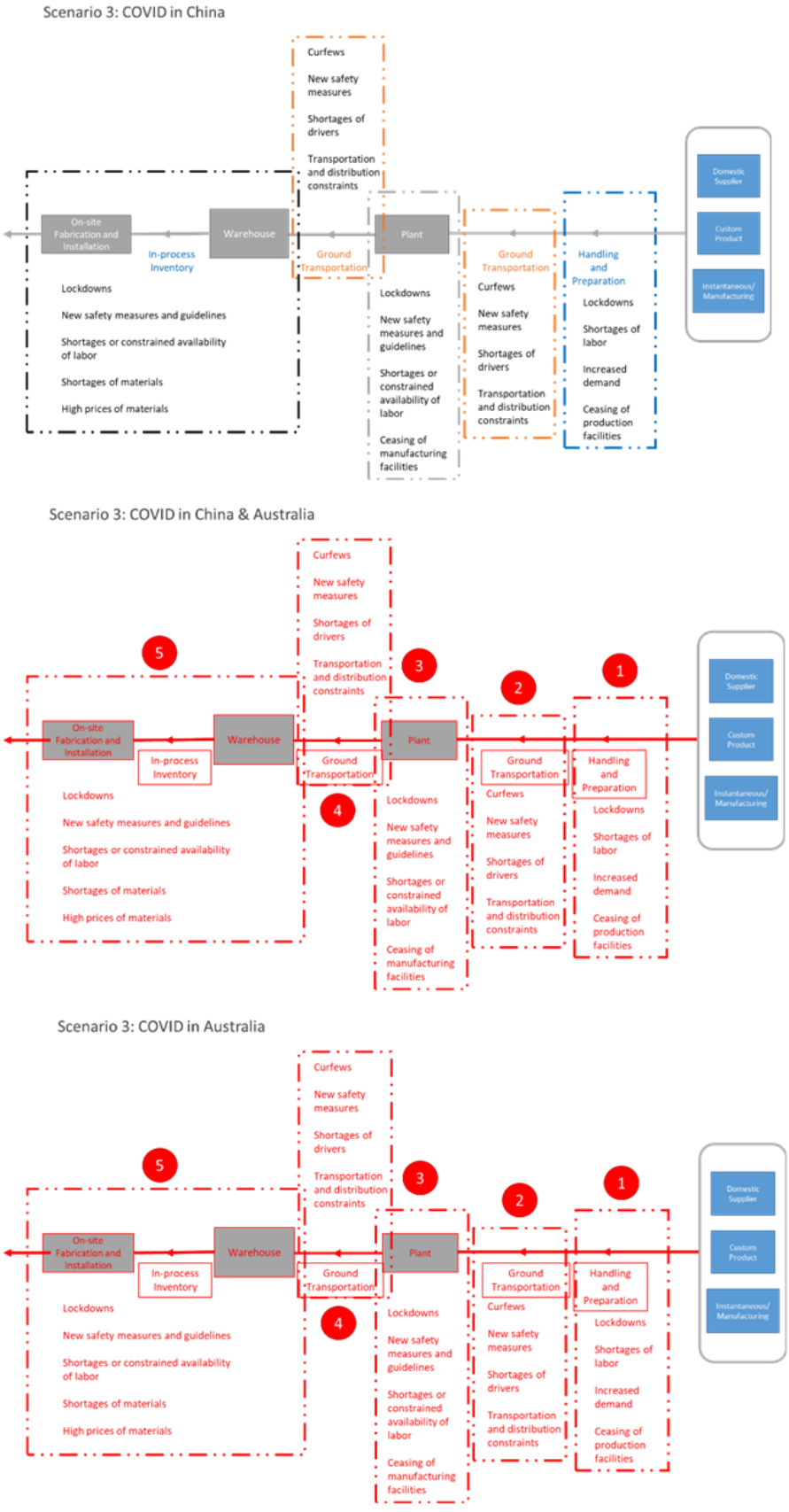

Figure 41: Scenario 3 Impacted Stages

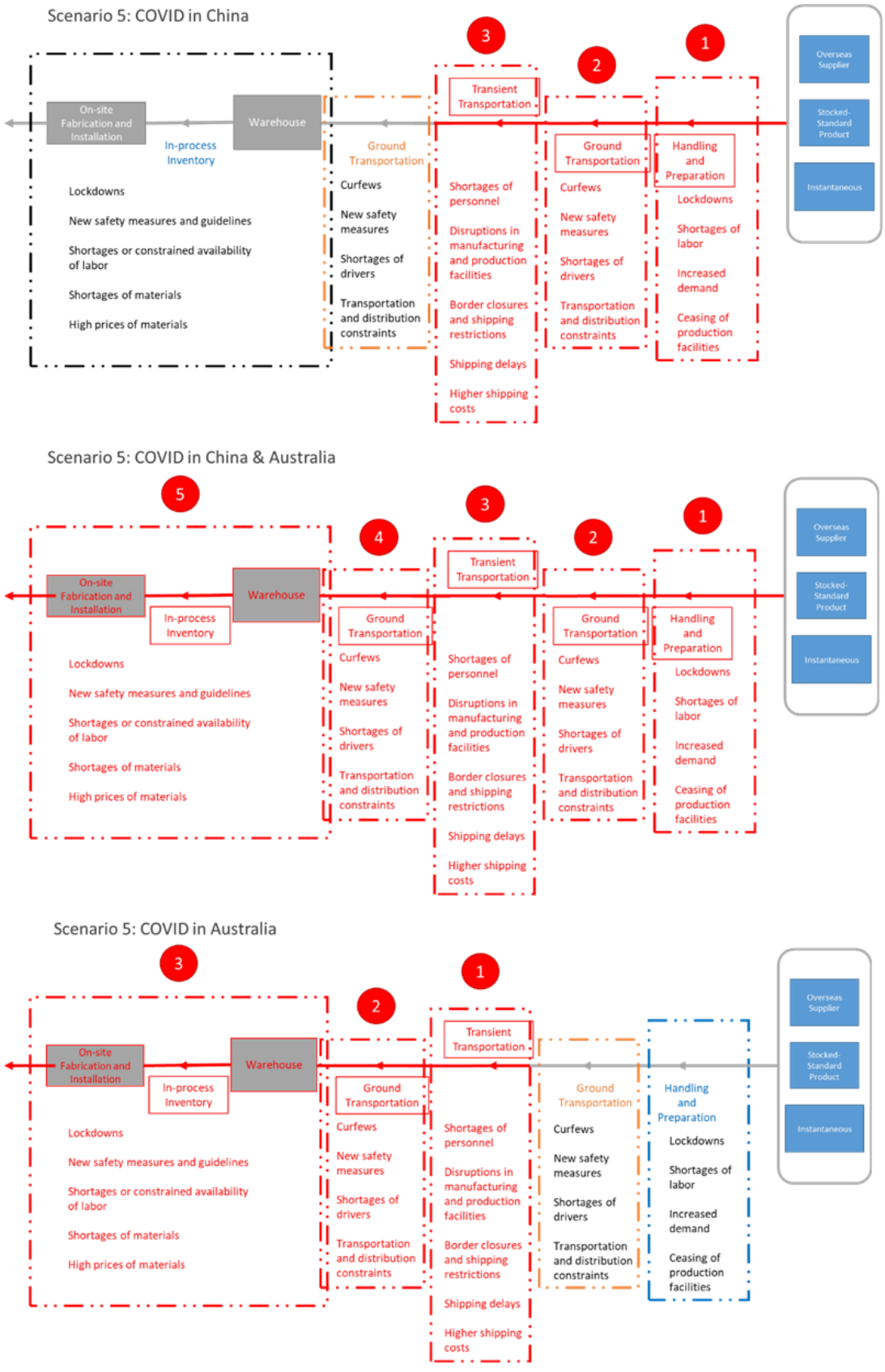

Figure 42: Scenario 5 Impacted Stages

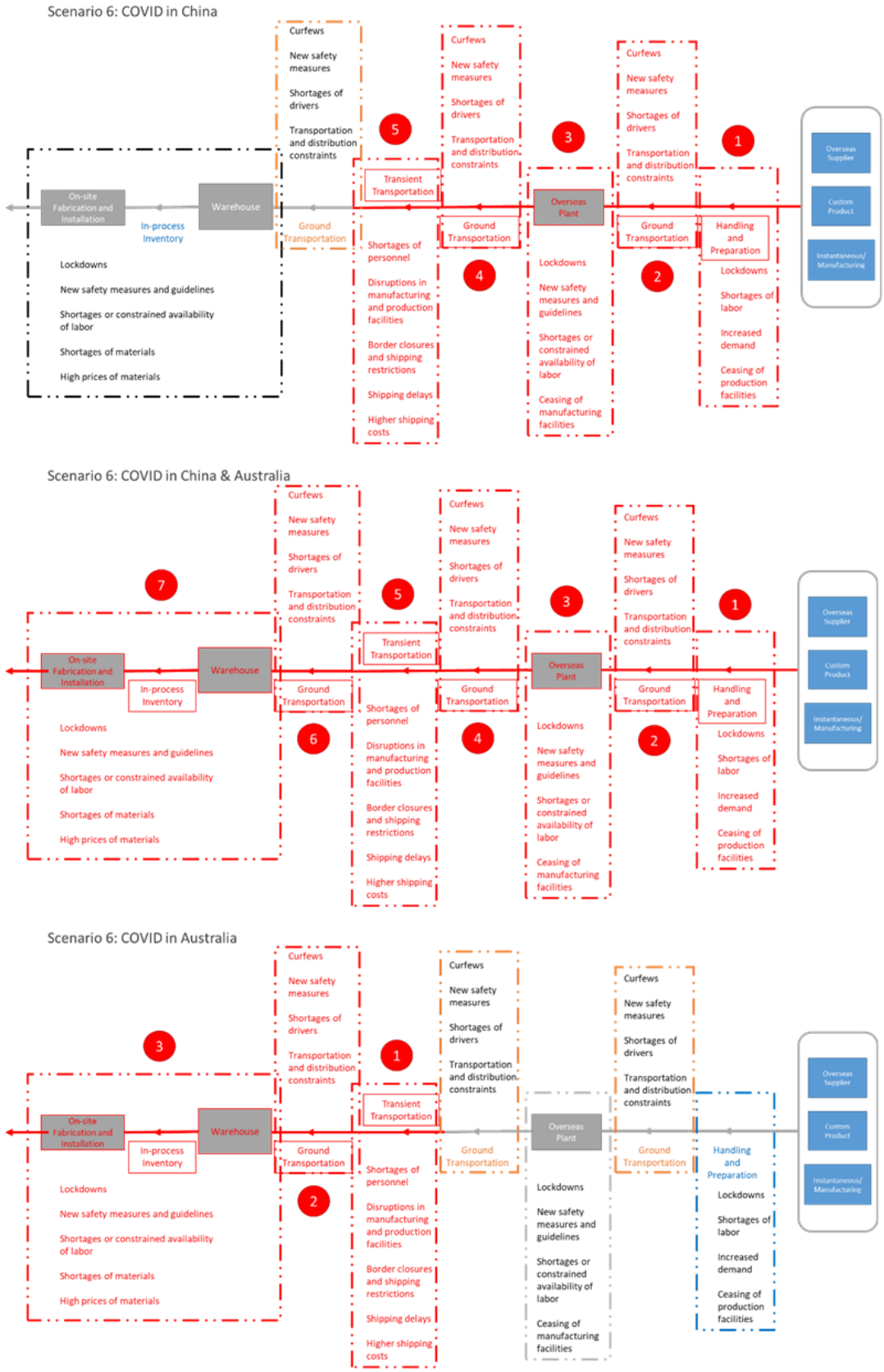

Figure 43: Scenario 6 Impacted Stages

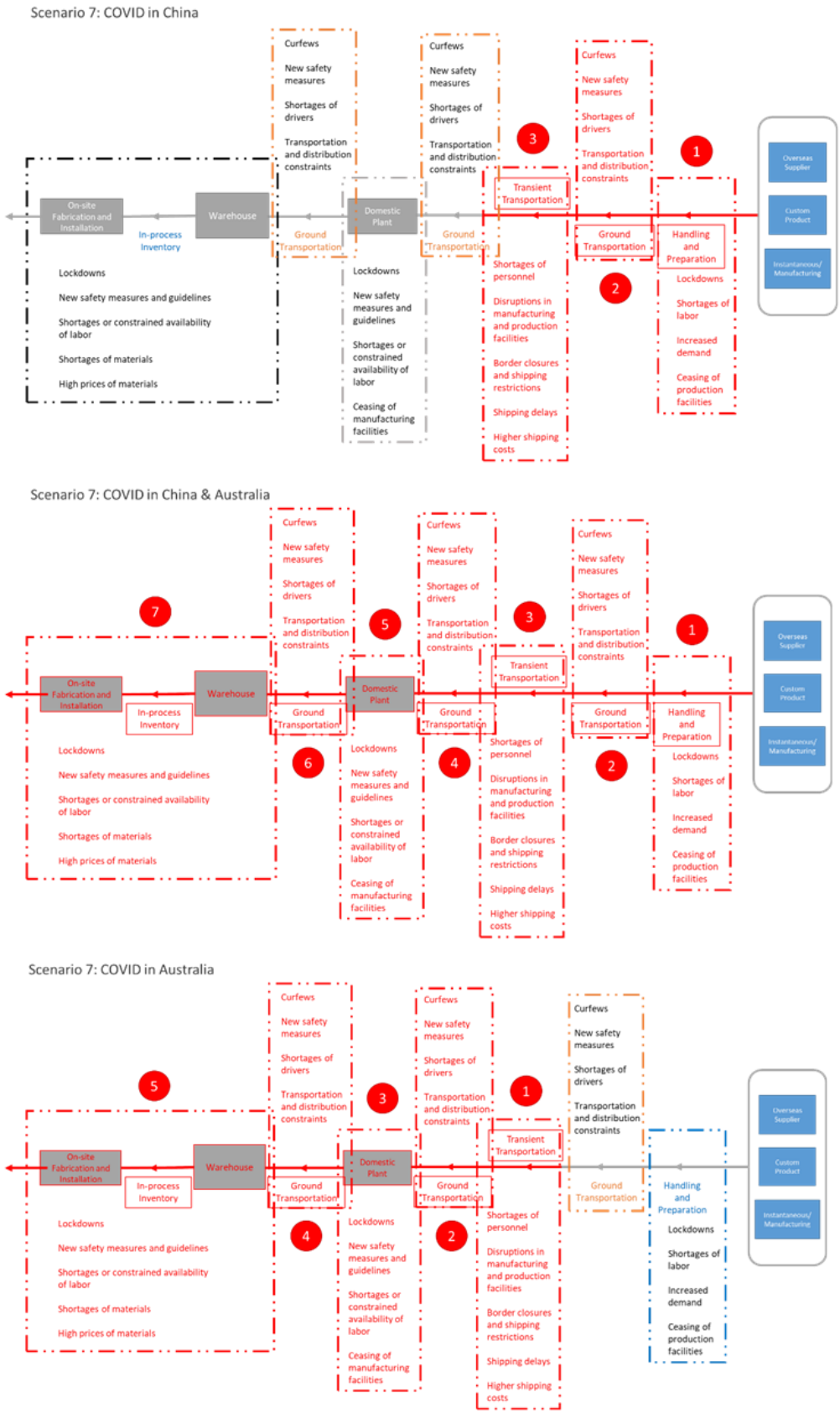

Figure 44: Scenario 7 Impacted Stages

CHAPTER 6

CONTRACTUAL AND LEGAL EFFECT OF LEGISLATIVE DIRECTIVES ON SUPPLY CHAIN

6.1. Preamble

Based on what was discussed in the previous chapters, this chapter complements the demonstration of the impact of COVID-19 on the construction supply chain, by presenting a case study that shows the effect of various legislative directives and acts on the chain, that were issued by different authorities throughout the pandemic era in response to its wide spread. The case revolves around a construction project in Saudi Arabia which, during a certain stage of construction, comprises the procurement of fabricated wooden components in multiple shipments from Turkey that had to be installed as part of the furniture.

The wooden components needed to be manufactured and fabricated in a plant in Izmir, inside Turkey. This entails that the materials once fabricated, they should undergo a ground transportation from the plant to port of Izmir on the north side of the Mediterranean Sea. After that, the batch had to be transported south along the sea, passing through the Suez Canal, and then over the Red Sea in order to reach the port of Jeddah in Saudi Arabia. The project is located inside Jeddah, the fact that encompasses again the involvement of ground transportation from the port to the construction site, where they should be installed.

Part of the procurement process involves taking measurements on-site and providing them to the manufacturer prior to manufacturing. In addition, the contract of this project entails that the Engineer and the Interior Designer had to visit the

manufacturing plant in Turkey. They had to inspect the quality of Veneer before it is pressed and glued onto the wood panels.

Although the project, and therefore the procurement process to be discussed, did not occur during the pandemic era, however the articulation of the events and consequences based on such a typical and comprehensive materials procurement case is important. The case comprises the state of an overseas supplier with the adoption of Just-In-time/Manufacturing supply chain mode. Both transportation means are included, ground and transient, to link the supplier with the construction site. Moreover, the fact that three countries are involved with the procurement process; Turkey, Egypt and KSA, makes the case a multi-jurisdictional one. Figure 45 depicts a simple presentation of the supply chain including the construction site activities, fabrication at plant, and several ground and transient transportation phases. Also, in between the two transient or marine phases falls the passage through Suez Canal phase.

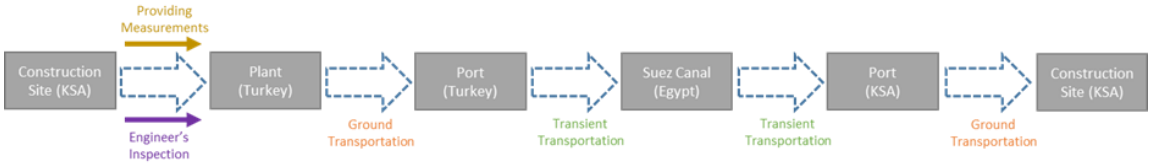

Figure 45: Turkey-Egypt-KSA Supply Chain

6.2. Legislative Directives

Whether in Saudi Arabia or Turkey, different measures, regulations and new norms have been spread in response to the pandemic, where people, companies and all sectors had to abide by and follow. These new regulations are issued, imposed and protected by the law, as they are considered as legislative directives coming from legal authorities.

In KSA for instance, reacting to the pandemic was depicted in several announcements or events that occurred on specific dates. Same inside Turkey and other countries in the world. Tables 13 and 14 shows the COVID related events in KSA and Turkey respectively, where some of these events are considered as legislative directives.

Table 13: COVID-Related Events in KSA

Event	Date
Travel ban to China	February 06, 2020
First confirmed case	March 02, 2020
Closure of all educational institutions	March 08, 2020
Imposing measures such as social distancing and masks	March 08, 2020
Restrictions at ports	March 09, 2020
Suspension of all sports competitions	March 14, 2020
Suspension of domestic flights, trains, buses and taxis	March 20, 2020
Suspension of international travel	March 21, 2020
Nation-wide curfew put into place	March 24, 2020
Full lockdown of Jeddah governorate including construction sector	March 29, 2020

Table 14: COVID-Related Events in Turkey

Event	Date
Travel ban to China	February 01, 2020
Stop all flights to and from Iran	February 23, 2020
Stop all flights to and from Italy, South Korea and Iraq	February 29, 2020
Restrictions at ports	March 03, 2020
First confirmed case	March 11, 2020
Extended flight bans	March 13, 2020
First death case	March 15, 2020
Closure of all educational institutions	March 16, 2020
Suspension of indoor activities of many businesses	March 16, 2020
Imposing measures such as social distancing and masks	March 16, 2020
Nation-wide lockdown and curfew put into place	March 21, 2020

Also in Egypt, several acts and directives were issued by the Egyptian authorities in order to contain the pandemic. The fact that three different countries are

involved, Turkey, Egypt and Saudi Arabia, makes the situation multi-jurisdictional, and thereby more complicated.

Starting form Jeddah, the project could be halted due to legislative directives forcing construction works to stop for certain periods of time, which is shown in table 13 as “Full lockdown of Jeddah governorate including construction sector”. The lockdown was imposed on March 29, 2020 by the ministry of interior where all public and private sectors had to comply with the orders including construction industry. And in case some projects were allowed to continue their works or resumed after certain time, the government had introduced from the beginning strict health measures and guidelines in all places including construction sites, such as masks and social distancing. Therefore, and for the activities that had to be performed on site, such as the dimensions and measurements that should be taken by the contractor as in this case, were either blocked completely by the suspension of the project or disrupted significantly by the new measures and guidelines.

Moving to Turkey, where the wooden components were being fabricated, the Turkish laws and jurisdictions apply at this stage. The manufacturing process could be impacted by the legislative directives and acts that forced the plants either to hinder their operations completely for certain periods, or to carry on but stringently abiding by the new safety regulations. Thus, here the directives come from the Turkish authorities at this stage. However, concerning the Engineer’s inspection and visit to the plant, this process could be affected by either the Saudi’s directives of border closures or by the Turkish travel restrictions and bans, and therefore, both of them should be considered for this task to be accomplished as requested by the owner.

Regarding the delivery process from the plant in Turkey to the construction site in Jeddah, the product has to be transported over the Turkish land into the port of Izmir, then shipped all the way to the port of Jeddah, passing through Egypt's Suez Canal, before it should be conveyed again inside the Saudi's borders to the project location. This multi-national situation makes the contractor more concerned about the different disruptions that might occur at any time due to one or more of the three involved countries. For instance, the ground transportation in side turkey could be disturbed by the curfew orders which were officially declared by the Turkish government on March 21, 2020. And once the product arrives to Izmir port, it could be stuck there for several days not only because of the closure of the Turkish port, but also due to the restrictions that could be put in place at the Suez Canal by the Egyptian authorities, or even the shutdown of Jeddah port by the Saudi Government. Even though the Egyptian authorities haven't issued orders for restricting the passage of ships through the Canal during the pandemic, but this could have been occurred any time, as it was evident at other Canals and artificial waterways around the world. Therefore, the contractor, coordinating with the manufacturer, should account for all these legislative directives before releasing the materials from the plant itself. In addition to the ground transportation that has to be undertaken between Jeddah port and the construction site, which in turn could be impacted by the curfews orders as well that were officially put in place in Saudi Arabia on March 24, 2020 by the Saudi Ministry of Interior.

This case is multi-national, and therefore it is multi-jurisdictional and affected by several authorities' acts. As per what has been witnessed worldwide, Covid-19 has been spreading diversely, at different times and at varied pace among countries and nations. This leads to the fact that new laws, legislative directives or acts have been

issued differently between governments, regarding timing, scaling and stringency. For that, the contractor should consider all authorities that could be involved in the procurement of the fabricated wooden components as in this example, as any legislative decision or procedure by any of the authorities would be of a significant impact on the whole procurement process. The above discussed legislative directives and acts are reflected on the supply chain diagram as shown in figure 46, and they are summarized with their impacts on the procurement of the wooden components in table 15 below.

The declaration and impose of the various legislative directives has contractual and legal effect. The contractual effect is manifested in the different contractual clauses that are triggered at each stage of the supply chain of the fabricated wooden elements and the base to claim for time or cost compensation based on contract clauses and sub-clauses. However, the legal effect is represented by the reliance on these legislative directives which are considered to be issued by lawful and governmental authorities to claim for extension of time or additional cost on a legal basis.

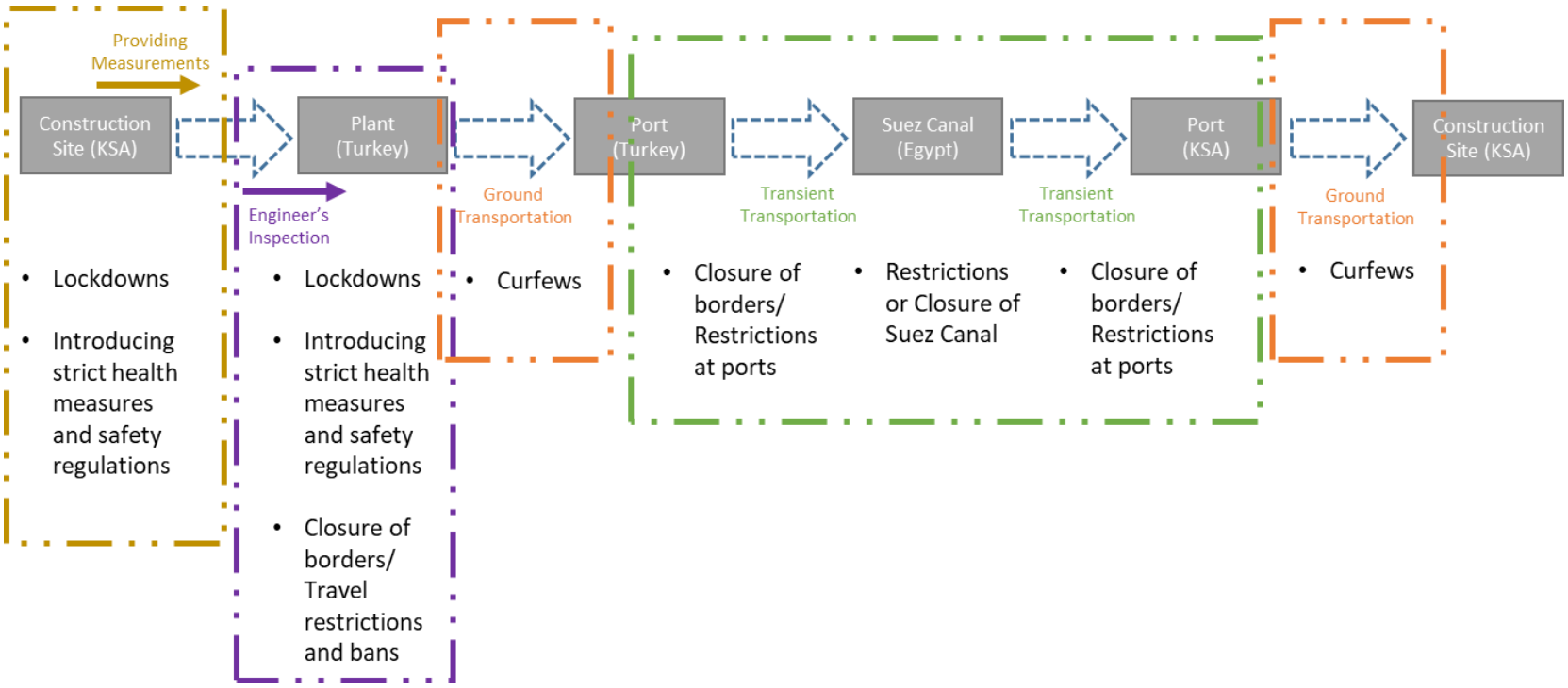

Figure 46: Legislative Directives at Each Stage of Turkey-Egypt-KSA Supply Chain

Table 15: Legislative Directives Impact on Fabricated Wooden Components Supply Chain

Stage	Legislative Directive	Country	Impact
Taking measurements on site	Lockdowns	KSA	Halting of construction works
	Introducing strict health measures and safety regulations	KSA	Slowing the progress of work at site
Manufacturing at plant	Lockdowns	Turkey	Hindering of plant operations
	Introducing strict health measures and safety regulations	Turkey	Slowing the progress of work at plant
	Closure of borders/Travel restrictions and bans	KSA	Preventing Engineer to leave KSA for inspection
	Closure of borders/Travel restrictions and bans	Turkey	Preventing Engineer to enter Turkey for inspection
Delivery	Curfews	Turkey	Disrupting transportation of materials from plant to port
	Closure of borders/Restrictions at port	Turkey	Delaying materials from leaving the port
	Restrictions or Closure of Suez Canal	Egypt	Delaying passage of materials
	Closure of borders/Restrictions at port	KSA	Delaying materials to enter the port
	Curfews	KSA	Disrupting transportation of materials from port to site

6.2.1. Contractual Effect

Referring to FIDIC 2017 conditions of contract, sub-clause 18.1 (Exceptional Events) defines Exceptional Event as an event or a circumstance which must fulfill the following four conditions: "(i) is beyond a Party's control; (ii) the party could not reasonably have provided against before entering into the Contract; (iii) having arisen, such Party couldn't reasonably have avoided or overcome, and (iv) is not substantially attributable to the other Party". This sub-clause (Exceptional Events) doesn't list global diseases or epidemics as events in the exceptional events' provision, as it includes a wide list of exceptional events or circumstances such as natural catastrophes, war, revolution, terrorism, and riot that are described under the six sub-paragraphs in sub-clause 18.1. However, sub-clause 18.1 explained that an Exceptional Event is not limited to the stated events provided that the four conditions that constitute an exceptional event or circumstance are satisfied. To this end, in terms of sub-clause 18.1 of FIDIC 2017, COVID-19 is considered as an Exceptional Event.

Regarding the stage where measurement should be taken on site in Jeddah and provided to the manufacturer, this task could be affected by either the suspension of the project due to governmental orders or by the imposed health measures. For the suspension imposed by the government, sub-clause 13.6 (Adjustments for Changes in Laws) states that "If the Contractor suffers delay and/or incurs an increase in Cost as a result of any change in Laws, the Contractor shall be entitled subject to Sub-Clause 20.2 [Claims For Payment and/or EOT] to EOT and/or payment of such Cost", where FIDIC 2017 defines Laws as "all national (or state or provincial) legislation, statutes, acts, decrees, rules, ordinances, orders, treaties, international law and other laws, and regulations and by-laws of any legally constituted public authority". Therefore, and in

accordance to sub-clause 13.6, the Contractor shall give notice to the Engineer under sub-clause 20.2.1 (Notice of Claim) and shall be entitled subject to Sub-Clause 20.2 (Claims For Payment and/or EOT) to an extension of time for any such delay under Sub-Clause 8.5 (Extension of Time for Completion), and payment of any such Cost which shall be included in the Contract Price. In addition, sub-clause 13.6 could provoke sub-clause 13.3.1 (Variation by Instruction) or sub-clause 13.3.2 (Variation by Request for Proposal) in case any change or variation to the execution of works becomes essential because of the change in Laws.

Furthermore, and even if the project was not fully suspended, the constrained availability of labors on site due to health regulations imposed by governmental authorities and which might cause significant delays (in this case delaying the task of taking the necessary measurements); could push the contractor to rely on sub-clause 8.6 (Delays Caused by Authorities) and hence, in accordance to this sub-clause and sub-clause 8.5 (Extension of Time for Completion), he/she could claim for time extension under sub-clause 20.2.

Also during this phase, and due to the health and safety measures that should be strictly followed, and complying with the contract terms, sub-clause 4.8 (Health and Safety Obligations) is triggered particularly in section (b) that states “The contractor shall comply with all applicable health and safety regulations and Laws”. The contractor shall comply with all the relevant labor Laws including safety at work laws in accordance with sub-clause 6.4 (Labour Laws). In addition, health and safety of workers should be ensured by all means especially during epidemics in accordance with sub-clause 6.7 (Health and Safety of Personnel) where it is stated in section (b) “the

contractor shall ensure that suitable arrangements are made for all necessary welfare and hygiene requirements and for the prevention of epidemics".

For the subsequent stages through which the product is being manufactured at the plant in Turkey, and then delivered all the way to the construction site in Jeddah, through ground transportation, marine and then through land again, the contractor shall manage the whole process in order to achieve the arrival of wooden components on time. The delays that are incurred due to the disruptions of the operations at the manufacturing plant, whether because of the lockdowns orders and shutdown of plants or as a result of the new strict health and safety regulations, drive the contractor to trigger and rely on the exceptional event sub-clauses, and same for the whole delivery process. Thus, once he/she becomes aware of any possible delay, a notice of event shall be submitted under sub-clause 18.2 (Notice of an Exceptional Event), in which the obligations that the contractor is prevented from performing it under the contract and the performance of which is or will be prevented due to the pandemic are being specified. And in accordance with sub-clause 18.4 (Consequences of an Exceptional Event), the contractor shall give a Notice of Claim under sub-clause 20.2, asking for an extension of time in accordance with sub-clause 8.5 and additional costs. The additional costs that the contractor could claim for mainly in this case are due to the increase in the prices of materials that was evident during the pandemic period.

Moreover, and during the manufacturing process, and particularly before pressing the veneer sheets to the wooden panels, the Engineer and Interior Designer were asked by the Employer to inspect the quality of veneer at the plant in Turkey, to ensure that they are being fabricated as per the specifications. Therefore, and due to the Employer's request, a contractual term is considered at this stage which is sub-clause

7.3 (Inspection) stating in part (b) (i) “The Employer’s Personnel shall, during all the normal working hours stated in the Contract Data and at all other reasonable times during production, manufacture and construction (at the Site and elsewhere), be entitled to examine, inspect, measure and test (to the extent stated in the Specification) the Materials, Plant and workmanship”.

All the above mentioned contractual clauses and sub-clauses are triggered and shall be considered because of the pandemic during the procurement process of the fabricated wooden products all the way from turkey to Jeddah, passing through Suez Canal. Table 16 demonstrates and summarizes the previously discussed contractual findings.

Table 16: Triggered Contractual Clauses

Stage	Triggered Clause/ Sub-Clause	Description
Taking measurements on site	sub-clause 4.8 (Health and Safety Obligations) section (b)	Contractor shall comply with all applicable health and safety regulations
	sub-clause 6.4 (Labour Laws)	Contractor shall comply with all the relevant labor Laws including safety at work
	sub-clause 6.7 (Health and Safety of Personnel) section (b)	Suitable arrangements shall be made for all necessary welfare and hygiene requirements
	sub-clause 18.1 (Exceptional Events)	Definition of the exceptional event
	sub-clause 18.2 (Notice of an Exceptional Event)	Contractor shall submit a notice of event once he/she becomes aware of any possible delay
	sub-clause 18.4 (Consequences of an Exceptional Event)	Obligations that the contractor is prevented or will be prevented from performing due to the event
	sub-clause 13.6 (Adjustments for Changes in Laws)	Contractor shall be entitled to time extension and payment in case of delays or additional costs due to changes in Laws
	Sub-clause 13.3.1 (Variation by Instruction) Sub-clause 13.3.2 (Variation by Request for Proposal)	If the change in Law leads to the necessity to vary the execution of works, Engineer shall either instruct a Variation or request a proposal

	sub-clause 20.2 (Claims For Payment and/or EOT)	If either party is considered to be entitled to additional payment and/or time extension, he/she can claim for such entitlement
	sub-clause 20.2.1 (Notice of Claim)	Claiming party shall give notice describing the event
	sub-clause 8.5 (Extension of Time for Completion)	Contractor shall be entitled to time extension if completion is or will be delayed
	sub-clause 8.6 (Delays Caused by Authorities)	Contractors works and obligations are or will be delayed due to regulations imposed by authorities
Manufacturing at plant	sub-clause 7.3 (Inspection)	Employer's Personnel shall be entitled to examine and inspect the Materials
	sub-clause 18.1 (Exceptional Events)	Definition of the exceptional event
	sub-clause 18.2 (Notice of an Exceptional Event)	Contractor shall submit a notice of event once he/she becomes aware of any possible delay
	sub-clause 18.4 (Consequences of an Exceptional Event)	Obligations that the contractor is prevented or will be prevented from performing due to the event
	sub-clause 20.2 (Claims For Payment and/or EOT)	If either party is considered to be entitled to additional payment and/or time extension, he/she can claim for such entitlement
	sub-clause 20.2.1 (Notice of Claim)	Claiming party shall give notice describing the event
	sub-clause 8.5 (Extension of Time for Completion)	Contractor shall be entitled to time extension if completion is or will be delayed
Delivery	sub-clause 18.1 (Exceptional Events)	Definition of the exceptional event
	sub-clause 18.2 (Notice of an Exceptional Event)	Contractor shall submit a notice of event once he/she becomes aware of any possible delay
	sub-clause 18.4 (Consequences of an Exceptional Event)	Obligations that the contractor is prevented or will be prevented from performing due to the event
	sub-clause 20.2 (Claims For Payment and/or EOT)	If either party is considered to be entitled to additional payment and/or time extension, he/she can claim for such entitlement
	sub-clause 20.2.1 (Notice of Claim)	Claiming party shall give notice describing the event
	sub-clause 8.5 (Extension of Time for Completion)	Contractor shall be entitled to time extension if completion is or will be delayed

6.2.2. Legal Effect

Based on this case study, and as per the results of chapter 3, the ultimate and eventual effects of Covid-19 on construction supply chain are materialized by the shortages in materials and increased prices as well. Hence, critical delays and cost impacts are imposed on the contractor by the end of the day. Therefore, and in pursue of his/her entitlement for time and cost compensations, the contractor can rely, beside the contractual clauses, on the laws and declarations issued by the government that could protect him/her to a certain extent and minimize the impacts of the disruptions. This protection by the government is provided because of the legislative directives that were introduced by legal authorities as preventive measures against the pandemic, in which they have been the major cause behind the disruptions in the supply chains. In this case, the contractor of this project which is located in Jeddah, could rely on the decisions of the Saudi government and Saudi Supreme Court.

In Saudi Arabia, COVID-19 was considered as an Emergency Situation according to the Supreme Court when a contractual obligation couldn't be implemented without unusual losses. This Emergency situation is subject to five conditions that had to be met:

1. the contract was put in place before the legislative directives related to the pandemic were imposed, and it continues during pandemic also
2. the contract should be directly affected by COVID, and the effect couldn't be averted
3. no other factors affecting the contract, only as a result of the pandemic

4. the aggrieved party has not compromised or waived its rights the aggrieved party must not have waived or compromised its rights under the contract
5. the effect or damage caused by pandemic cannot be dealt with by a separate law or decision.

In order to achieve justice, Saudi courts could amend the contractual obligations that were affected by the pandemic.

For the delays or the inability to fulfill a certain contractual obligation to perform works due to the unavailability or shortage of materials caused by the pandemic, the court has the power to suspend this obligation for a temporary period in case the unavailability of materials is temporary, or to terminate the contract at the request of any of the parties. Also, the court has the power to prevent the application of delay penalty clause or any other fines when the performance of a contract is delayed because to the pandemic.

In case of increase in the price of materials and products because of the impacts of COVID-19 preventive measures, if the increase is only temporary, then the court can suspend the contractual performance for the price increase duration, and if it is an absolute increase, the court has the power to increase the contract price as appropriate, where the employer in his turn has the right to request termination of the contract due to the increase in price.

Only disputed contracts should be considered by the courts, and damages should be assessed only for the period of the impacts of the pandemic on the contract. All this should be conducted and assessed by experts.

In addition, the Ministry of Finance issued a circular to all entities stating that delays in works or procurement due to the pandemic, would entitle contractors extension of time under Article 74 of the Government Tenders and Procurement Law (GTPL). The circular stated that the contract duration should be extended with penalty exemption in case the contractor suffers delays which is attributable to government entity or due to emergency or an order which was issued by governmental authority to suspend works, and which is beyond the contractor's control.

Therefore, claims could be brought and pursued legally, under the protection of the law, seeking time extension and cost compensation. The nature of this disruptive event, the pandemic, led to the issuance of new laws or legislative directives by official and legal authorities, which have been a major reason behind the disruptions in the supply chains and materials procurement processes. Hence, and beside the construction contractual claims that are usually dealt with based solely on the contract clauses and sub-clauses, the legal effect of the legislative directives has set for legal basis of claims.

CHAPTER 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1. Summary of Work

The research discussed the severe impacts of Covid-19 on the construction industry and particularly on its supply chain and the materials procurement process. The literature review revealed remarkable disruptions and breakdowns in this chain resulting eventually in shortages in building materials and significant increases in their prices. The impact of the pandemic has been observed on different levels due to the ripple effect which characterized it and because of the complex nature of the construction supply chain. The direct effects of the virus led to further disturbances in the elements composing the supply chain, which in their turn resulted in delays and increased costs that were felt on ground by the end of the day. The study also demonstrated comprehensively the components and different paths of the materials procurement process, depending on several factors which are: type of product, type of supplier, and mode of supply chain. This has generated various scenarios which differ in the level of complexity and hence to the extent they were or could have been disrupted by the pandemic. Moreover, the study discussed and manifested, through a supply chain case study between turkey and KSA, that the major impacts of the pandemic are represented in the legislative directives and acts that have been issued by the governmental and legal authorities inside each country, aiming to contain the spread of the virus which is characterized by its rapid diffusion between people. These directives contractually lead to the provoke and trigger of several contract clauses and sub-clauses, especially for the sake of claiming for extension of time and compensation of costs by contractors. In

addition, and beside the claims that can be pursued contractually, the research showed that such directives or acts can lead and set up for legal claims to arise inside the courts as well.

7.2. Conclusions

Since the emergence of Covid-19 pandemic in Wuhan, China, the global construction supply chain started sensing the risks and breakdowns that might occur to the distribution of building materials and products between countries, especially due to the significant and paramount position of China in the global construction economy. Later, and with the rapid spread of the virus between nations, projects' stakeholders have recognized the disastrous situation that they were stuck in.

The ultimate consequences of Covid-19 on building materials were demonstrated in significant shortages or delays, and remarkable rise in their prices. These consequences did not come from the initial and direct impacts the pandemic, but from subsequent effects and disruptions in the construction supply chain. This emphasizes the ripple effect of the pandemic within the supply chain components. The impact of this disruptive event on supply chain was shown on three major levels. The intuitive level 1 effects where almost all sectors and industries were affected, including the construction sector, due to the influence of the virus on human health and the associated measures taken in response to the disease, such as lockdowns, social distancing and border closures. This has led to disruptions and breakdowns on another level, where workforce, manufacturing, transportation and shipping were either halted or interrupted. Then, the eventual consequences which resulted from all these mentioned

effects were manifested either in materials shortages or higher prices, and considered as level 3 impacts.

The intensity of disruptions varies depending on the complexity of the procurement process that is put in place. And this complexity relies on certain factors; the type of product whether it is stocked-standard or customized, the type of supplier whether it is domestic or overseas, and the adopted supply chain mode whether it is instantaneous, manufacturing or Just-in-Time. Also, the length of the chain constituting the elements and phases that the product should pass through before reaching the construction site plays a major role in defining how complicated the process is. It was evident that the combination of custom product, overseas supplier and Instantaneous/Manufacturing mode is the longest and most complicated due to the involvement of many stages, thereby making the procurement process more vulnerable against disruptions and thus prone to several breakdowns before the product can arrive to the site.

All the studied and identified issues and disturbances in the supply chain of construction materials during the whole pandemic era, have raised many concerns pertaining the implementation of construction contracts and fulfilling the contractual obligations by contractors. The disruptions in the supply chain, whether at the construction site, in the plants and manufacturing facilities, inside the country or outside, have led to significant delays especially due to the shortages in building materials and products, in addition to the rising prices. Thus, and seeking to avoid losses as much as possible, projects' stakeholders try to protect themselves by all means. Contractually, parties rely on all relevant contract clauses and sub-clauses claiming for time and money compensation. Whether COVID-19 can be considered an "Exceptional

Event" or not, has been the first major concern for stakeholders and especially for contractors. This was being aggravated as global pandemics and epidemics are not stated among the Exceptional Events' examples in the contract as per FIDIC 2017. However, the definition of an Exceptional Event according to sub-clause 18.1, and the statement that an Exceptional Event is not limited to the mentioned events, together provide a solid evidence to consider the pandemic as Exceptional Event. For that, all related contract clauses and sub-clauses in this regard have been triggered, in addition to other sub-clauses pertaining time, claims and materials. The case study examined in this research, where fabricated wooden components are delivered from Turkey to KSA passing through Suez Canal, provided comprehensive and clear demonstration of the triggered contractual clauses, and showed a clear path for aroused claims in this regard. However, and because the harsh impacts of the pandemic on the construction supply chain came from the legislative directives, acts and measures issued and imposed by governments and related authorities, courts and laws had their interference and effect to certain remarkable extent on mitigating the consequences of the pandemic on projects' stakeholder and especially the contractors. The legal effect of the introduced legislative directives paved the road for legal basis of claims, where courts hold the power to amend contractual obligations that were deemed to be affected by these directives during the pandemic period in order to attain justice.

7.3. Recommendations/Practical Implications

The research provides a comprehensive understanding of the impacts of the COVID-19 pandemic on construction supply chain and materials procurement. It describes the circumstances that have been prevailing during the whole pandemic period

and the disruptions that were striking each component of the supply chain. The findings of this study can be utilized as recommendations for project stakeholders to be well prepared for such disruptive events in future projects in order to mitigate the harshness of their impacts. All stakeholders shall ensure the proper drafting of the contract to minimize ambiguities and uncertainties when an unprecedented event occurs. The selection criteria of suppliers emphasized it importance during this era, and this should be precisely taken into consideration for future projects. Suppliers are the source of materials which have been the major barrier in front the continuity of many projects around the world since 2019. Moreover, project participants shall allow for flexibility in design as much as possible, so that contractors, and in case of the occurrence of similar disruptive event, will be able to make changes or go for alternative designs and products that may be affordable at that time. Even though the contractor is usually the first party who is exposed to risks in such cases, however this exceptional event showed, to a certain extent, different approach to the consequences especially from courts and laws. Therefore, it is recommended to emphasize and promote the negotiation between all stakeholders, and enhance the risk sharing strategies in order to survive such disruptions with the least possible losses.

7.4. Research Limitations

The research demonstrated the effect of COVID-19 on construction supply chain which involves numerous participants. All participants and relationships between them have been affected by the pandemic, including the first tier suppliers providing raw materials. These suppliers and the disruptions at these levels are not deeply discussed in this research, and that is because of the limited resources and papers in this regard. In

addition, the research did not discuss comprehensively the projects that were able to survive the pandemic with the least losses and interruptions due to the limited articles and case studies about such projects and about the strategies they were adopting. Further, the KSA-Turkey case study did not occur during the pandemic period, but it was studied because the data about the procurement process are available and it represents a solid example of a typical supply chain. Also, the legal pursuit and defense of claims is limited to the what was issued by Saudi Supreme Court, since dealing with the impacts of the pandemic on construction contracts is still disputed and depends on the laws of each country.

7.5. Future Work

This research provides a valuable base for further more comprehensive studies on the impacts of such disruptive events on construction and especially on it supply chain. Future studies can rely on the findings of this research to develop strategies and immune systems for the sake of protecting construction projects and materials procurement processes, and mitigating the consequences that may rise from inevitable future disruptions which will hit the construction sector. Moreover, more future work can be done on construction contracts, the amendments that may be introduced and the proper drafting criteria. Also, studying the intervention of laws and courts in resolving and amending contractual obligations can be further discussed by researchers in the future.

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