

Supply Chain Risk Management Strategies in the Face of COVID-19

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Abstract

The COVID-19 pandemic devastated businesses worldwide and the global economy contracted as companies grappled with shocks to demand and supply. The purpose of this research is to understand the impact of COVID-19 in industries, identify risk management strategies employed by companies, and recommend methods businesses may consider in selecting suitable strategies to combat future pandemic risks. Ten companies across five industries globally were studied, from which eleven distinct strategies in managing COVID-19 disruptions were identified. Our results suggest that there was no universal risk management strategy against COVID-19 that could have been employed by any company, nor was there a strategy unique to a single industry. It was observed that each company employed more than one strategy towards the COVID-19 pandemic disruption, but establishing partnerships was the most frequently employed strategy. Finally, we propose two contingency and typology frameworks, namely the Shock-Responsiveness Framework and Effort-Impact Framework, to aid companies in determining suitable types of risk management strategies to minimise the impact of future pandemic risks.

Keywords

COVID-19, pandemic risk, risk management strategies, supply chain strategy framework, comparative case studies

1. Introduction

Industries and supply chains are dynamic and evolving according to the economic landscape. In the face of risk, companies that fail to respond or prepare for disruptions can fall behind the competition. The Coronavirus Disease 2019 (COVID-19) is a viral pneumonia which had spread across the world, with an accumulated 17 million cases and 675 thousand deaths as of 1 August 2020 (World Health Organisation, 2020). To curb the spread, countries entered lockdowns and governments worldwide imposed measures such as social distancing, work-from-home schemes and local/international movement restrictions. COVID-19 resulted in an unprecedented decline in global activity and companies struggled to sustain their businesses. In the first quarter of 2020, global trade contracted by 3.5 per cent, with a severe restriction on mobility of people and goods, as well as a global loss of 130 million full-time jobs (International Monetary Fund, 2020). This study seeks to examine supply chain risk management strategies based on multiple case studies to shed light on how companies had reacted or equipped their supply chains against pandemic risks, with the following research questions:

- How has COVID-19 impacted companies and their supply chain stability?
- How have companies fortified their supply chains to sustain their businesses amid the pandemic?
- How should companies determine suitable types of risk management strategies to employ to minimise the impact of future pandemic risks on their businesses and supply chain stability?

2. Literature Review

COVID-19 disrupted businesses and supply chains worldwide. This section first examines the phenomenon of supply and demand shocks, followed by recent studies on the concepts of Supply Chain Resilience (SCR) and Supply Chain Risk Management (SCRM), especially in the context of COVID-19.

2.1. Supply Chain Shocks

Governmental measures imposed to ensure the safety of its citizens can cause a devastating supply shock on businesses. Del Rio-Chanona et al. (2020) conducted a study on 740 occupations in the United States spanning various

industries to study supply shocks caused by COVID-19, through examining the extent of the impact of work-from-home measures on work activities. They found that 56% of employees in multiple sectors such as manufacturing and mining could not work from home due to the nature of their jobs, resulting in labour supply shock. Farrell and Newman (2020) added that specialisation for a country "can create unexpected fragility in moments of crisis" due to an over-focus on a specific product or sector, leading to a reliance on imports from other countries to fulfil its other needs. When COVID-19 triggered lockdowns worldwide, the movement of goods between countries was obstructed as movement restriction measures were implemented, cutting off the supply of imports and triggering material supply shocks. Hiroyasu and Yasuyuki (2020) applied an input-output model to a case study of Tokyo (Japan) to simulate how lockdown of a single city in the country propagates its economic repercussion upon itself and its neighbouring districts. The model was based on specific assumptions on firms such as fixed suppliers, customers and supply chain, with its parameters calibrated against a past case study on the Great East Japan Earthquake in 2011 for 2 months. The study concluded that the lockdown of a single city led to a fall in production in Japan by 86.1%. Furthermore, the impact of an extended lockdown for Tokyo caused an even larger impact on the surrounding region that suffered greater production losses compared to Tokyo itself.

Aside from supply shock, demand shock experienced by industries disrupted supply chains and their businesses in terms of revenue loss. Baker et al. (2020) researched on the COVID-19 impact on household consumption of 44,600 individuals between January to March 2020. They found that all types of household spending saw a peak in expenditure in mid-February, followed by a significant dip in the following month. Their results also suggest that reduced and restricted movements by the COVID-19 pandemic subsequently dissuaded consumers from purchasing goods and services altogether. Similarly, del Rio-Chanona et al. (2020)'s study on the impact of COVID-19 on consumer demand for various industries showed that key industries such as transport, entertainment and restaurants were heavily affected by consumers as they stopped purchases to avoid the risk of infection. Conversely, the pandemic also triggered positive demand shocks that resulted in key sectors experiencing severe shortages due to their inability to cope with the demand surge. Kamerow (2020) examined the surge in demand for medical supplies in the United States as the COVID-19 pandemic worsened. Within a month of the spread of COVID-19, the country faced a shortage of Personal Protective Equipment (PPE) like face shields, gowns and face masks, which led to an inflation in prices as producers struggled to keep up with the demand. Litton et al. (2020) conducted a study in Australia to analyse the capability of Intensive Care Units (ICU) in Australia to cope with a positive demand shock as a result of the pandemic by analysing data from an ICU surge capability survey as well as some field data. It concluded that hospitals would have to hire 150% more doctors and 169% more nurses, as well as more medical equipment such as ICU beds to support the surge in demand. Nikolopoulos et al. (2020) modelled the excess demand for products and services during the pandemic and predicted the panic buying effect and respective excess demand for groceries and electronics during the current wave of COVID-19. Furthermore, their results show that, the earlier the lockdown is imposed and the longer the lockdown lasts, the higher the excess demand for groceries.

Importantly, demand and supply shocks are often inter-related and may even lead to a vicious cycle. Guerrieri et al. (2020) examined the pandemic to investigate how negative supply shocks result in a large change in demand compared to the shock itself. The investigation was conducted via modelling on several aspects of the economy, which found that supply shocks from COVID-19 triggered panic buying in consumers, resulting in a sharp rise in demand, followed by a dip as workers lost their incomes and purchasing powers.

2.2. Supply Chain Resilience

Supply chain resilience (SCR) is a concept that has long preceded the events of COVID-19. SCR strategies are measures that companies plan to counter potential future risks, such as to minimise their consequences on the supply chain should they occur, by employing these strategies upon detection of such risks (Annarelli and Nonino, 2016). For example, Kumar and Anbanandam (2019) conducted a study on 112 senior managers to examine the correlation between antecedents of SCR such as information sharing, visibility and agility, with SCR itself, as well as supply chain performance. They concluded that SCR and its antecedents are interdependent, with most factors directly impacting supply chain resilience, and that risk management culture is crucial toward SCR and ultimately risk mitigation. The importance of information sharing is also emphasised by Li et al. (2016) who examined a three-echelon supply chain comprising four suppliers to study the importance of information sharing towards improving SCR. Their study concluded that full information sharing is optimal as a resilience strategy to minimise the impact of risks, since it enhances the speed of recovery for supply chains in the event of disruptions.

However, appropriate supply chain resilience strategies are also contingent on the nature of risks and firm characteristics. Namdar et al. (2017) constructed an SCR decision model for sourcing to aid businesses in mitigating potential risks and evaluate the effectiveness of varying mitigation strategies towards different risks. The results show that: 1) For high-impact low-frequency risks, less risk-averse companies should have single suppliers and invest in supplier recovery and warning capabilities as it is more cost-efficient, while highly risk-averse companies should have multiple suppliers and invest in diversification and spot purchasing; 2) For low-impact high-frequency risks, companies (regardless of risk aversion levels) should have multiple suppliers and invest in diversification for cost efficiency. Separately, Dixit et al. (2020) conducted a study on 23 companies in India to assess the level of SCR within a company and its correlation with the Conditional-Value at Risk (CVaR). SCR is measured as a function of connectivity, network size, density and centrality of a company. The study suggests that companies with low density and centrality but high connectivity and network size possess higher resilience.

COVID-19 has unsurprisingly prompted numerous recent academic research on supply chain resilience. Singh et al. (2020) simulated a public distribution system (PDS) network to demonstrate disruptions in the food supply chain due to COVID-19. Their results suggest a system of integrated warehouses can mitigate disruptions at a single warehouse by fulfilling demand using stocks from a backup warehouse, raising service level for rice from 59% to 85%. Yet, in the context of an extraordinary event such as COVID-19, supply chain resilience is not just the focus of some firms but also more fundamentally survivability. Ivanov and Dolgui (2020) define viability as the “system ability to meet the demands of surviving in a changing environment”. They propose a decision-making environment that considers intertwined supply networks (ISN) and viability to ensure the survivability at a large scale. Ketchen and Craighead (2020) point out that while supply chain research on resiliency focuses on large firms, creative supply chain solutions became essential during the COVID-19 pandemic, especially at smaller firms, for which traits such as entrepreneurial orientation, optimal distinctiveness and bricolage would be important.

2.3. Supply Chain Risk Mitigation

Supply Chain Risk Mitigation (SCRM) refers to the management of risks upon their detection to fortify the entire supply chain (Jüttner et al., 2003). For example, to mitigate risks, Kirilmaz and Erol (2016) proposed the use of a procurement plan comprising 5 stages. The strategy was numerically evaluated and applied to an automotive company in Turkey to validate the strategy using a case study application. DuHadway et al. (2017) conducted a study to draw a link between various SCRM strategies with different disruptions. They categorised different supply chain risks according to their origins, i.e. internal or external to the firm, and inadvertent or intentional. They developed a framework that recommends strategies companies may choose to employ should depend on the risk at different stages (detection, mitigation or recovery), as well as the type of risk (intentional or inadvertent). Similarly, Manhart et al. (2020) conducted a meta-analysis with 26 research papers to examine a proposed framework for buffering and bridging supply chain strategies toward SCRM. This study was conducted using text mining and hypothesis testing to discover the relationship of buffering and bridging strategies with culture, SCRM, as well as the relationship between risk management and performance. The authors concluded that cultural differences influence the effectiveness of supply chain bridging and buffering as a strategy, but both strategies were effective in improving risk management and ultimately, improve the performance of the firm. El Baz and Ruel (2020) surveyed 470 French firms on the impact of COVID-19 on supply chains. They found that SCRM practices (i.e. identification, assessment, mitigation and control) all positively influence supply chain resilience.

3. Methodology

This research utilises a case study approach on a contemporary phenomenon – the COVID-19 pandemic. We examine the impact of this phenomenon on the companies as well as response strategies that companies adopted. Case studies are employed in research when there is an empirical analysis toward an investigation involving multiple phenomena that occur in response to real-life contexts and scenarios in which experimental landscapes are unable to account for (Yin, 2017). However, some case study research may be prone to over-generalisation (Hodkinson & Hodkinson, 2001), whereby investigations are constrained to the scope and impact at the companies investigated, which may not be representative of the business environment as a whole. According to Eisenhardt and Graebner (2007), a method to expand the scope of case studies to construct theories representative of a broad subject would be to use multi-case studies. Thus, this research examines ten case studies across five industries – Healthcare, Retail, Grocery, Logistics and Agriculture – for a broad-based representation of the impact and response measures employed by companies in the face of COVID-19. Companies have been selected mainly based on the amount of public information available (such as from news releases and financial statements), as well as to achieve a mix of small to large firms in countries

around the world. In the following sections, each case company is first introduced to offer a context of its scope of operations. Next, we identify the consequences of COVID-19, focusing on the demand and supply shocks in their supply chains. The study then examines strategies these companies employed in response to the pandemic. Subsequently, to evaluate suitable risk management strategies to employ when countering pandemic risks, we take a comparative approach across three axes of comparison – horizontal, vertical and transversal, an approach recommended by Bartlett and Vavrus (2016). In this research, the horizontal axis compares case studies across multiple industries, while the vertical axis compares various scales of business – from local to multi-national companies. Finally, the transversal axis compares the state of businesses before and after COVID-19 to understand its impact across time.

4. Data Collection

This research is based on data from ten companies across five industries as mentioned in Section 3, using a mix of primary and secondary data. Primary data was collected from one company under the pseudonym “Logistics SG”, with information regarding the demand and supply shocks experienced by Logistics SG, as well as strategies that the company had employed during the COVID-19 pandemic. For the other nine companies, secondary data was collected through analysing and consolidating information from press releases and financial statements by the respective companies as well as news articles on demand/supply shocks experienced and strategies these companies employed to strengthen their supply chains. Table 1 presents a summary of the ten case companies examined in this research.

Table 1. Description of Case Companies

Industry	Company	Description
Retail	L'Oreal	The world's largest cosmetics company, L'Oreal serves 130 markets, with 150 distribution centres and 40 factories globally fulfilling 16 million orders annually.
	Decathlon	Global sporting goods retailer Decathlon operates more than 1,500 stores in 57 countries. They manufacture and distribute in-house brands such as Domyos and Quecha across 55 sports.
Healthcare	CVS Health	CVS Health is a US-based healthcare company selling pharmaceutical products online and through 9,900 physical pharmaceutical stores across 49 states. CVS also runs 1,100 medical clinics.
	GE Healthcare	Part of General Electric (GE), GE Healthcare develops and sells products and solutions focused on diagnosis, patient monitoring and enterprise software and solutions.
Grocery	Walmart	Multinational grocery and hypermarket corporation Walmart runs 11,496 stores worldwide (Walmart, 2020c) and more than 150 distribution centres in the US alone.
	Carrefour	Multinational hypermarket corporation Carrefour has 12,225 stores across 30 countries worldwide serving more than 77 million customer households.
Logistics	Logistics SG	Singapore-based logistics company Logistics SG provides services such as procurement, warehousing and distribution across multiple sectors such as Healthcare and Aviation.
	Park N Parcel	Park N Parcel is a Singapore-based enterprise that offers transport services of goods from distribution points to shared pick-up points such as malls and public areas.
Agriculture	Shinrinno Farm	Shinrinno Farm is a Japanese free-range dairy ranch that produces and sells cow products from fresh Jersey milk to leather (Shinrinno Farm, 2020b).
	Belgian Potato Industry	Belgium is the world's largest frozen potato exporter, producing 5.3 million tons of processed potato products annually serving 160 countries (Biesemans, 2020). These products are typically sold in bulk to grocery stores or restaurants.

5. Results and Discussion

The following section examines the impact of COVID-19 on each company/industry before discussions on the various strategies each company implemented in managing COVID-19 pandemic risks.

5.1 Impact of COVID-19

The *retail industry* faced a negative demand shock and positive supply shock, as well as positive demand shock and negative supply shock – varying according to the nature of business and its products or services. L'Oreal faced a loss in revenue from its physical stores when it closed most of its stores and hair studios as governments forced brick-and-mortar stores to close during lockdowns. This resulted in a negative demand shock as consumers were unable to patronise its stores. In Q1 of 2020, L'Oreal's sales fell by 4.8%, though relatively better than the cosmetics market in general whose like-for-like sales fell by 8% (L'Oréal, 2020). Conversely, Decathlon faced a positive demand shock

from demand surge for indoor exercise gear, where bodybuilding and yoga equipment faced a 43% increase in sales as people look to home exercise as an alternative to outdoor activities (Lee, 2020).

The *healthcare industry* faced a positive demand shock and negative supply shock on most of its products and services. COVID-19 resulted in a surge of patients admitted to hospitals, overwhelming available hospital beds and medical equipment worldwide. Within months, GE Healthcare faced a positive demand shock with a demand rise of 880,000 medical ventilators globally (GlobalData, 2020), resulting in severe shortages (Mishra, 2020). The supply shock worsened due to forced closure of manufacturing facilities, resulting in production halts (Light et al., 2020). The pandemic triggered panic buying of medical products, where CVS Health faced a 300% increase for prescription delivery (LaVito, 2020), as well as a positive demand shock for hand sanitisers and masks (Meyersohn, 2020).

The *grocery industry* faced a positive demand shock and negative supply shock as consumers began to panic-buy during the pandemic. Lockdown measures incited consumers to hoard common household items and food as they prepare to remain home over the lockdown period (Nikolopoulos et al., 2020). Hypermarkets like Walmart and Carrefour faced a positive demand shock for critical goods like toilet paper and canned food at both physical and online stores. Carrefour and Walmart both faced a negative supply shock of manpower and capacity to support the surge in demand (Walmart, 2020d; Carrefour, 2020a).

The *logistics industry* faced a mix of positive and negative demand and supply shock, depending on the services provided and the clientele. Logistics SG faced a negative demand shock on some of its sectors as there was little to no work activity for its clients, resulting in an 80% fall in demand relative to its regular operations. This resulted in a positive supply shock as there was a surplus of goods left unused such as food rations that were at risk of obsolescence due to their perishable nature. Conversely, its customers in the healthcare sector faced a positive demand shock from a demand surge for logistical services and goods such as surgical masks and personal protective equipment, resulting in a negative supply shock as the sector's infrastructure and manpower were overwhelmed. Park N Parcel faced a negative demand shock as they were unable to execute their services due to the closure of public pick-up points such as malls, where 90% of their drop-off points were forced to close (Tan, 2020). Park N Parcel then faced a positive supply shock due to the excess, unused assets such as transport vehicles from the lack of demand.

The *agriculture industry* faced a negative demand shock and a positive supply shock from a surplus of produce. Japan's milk industry faced a negative demand shock from a 30% fall in demand for fresh milk as local consumers purchased food with longer shelf life in the face of lockdowns, and a 50% fall in demand for raw cream as restaurants closed (The Straits Times, 2020). This resulted in a positive supply shock from an excess of fresh milk and cream from cows as farms need to regularly milk their cows to maintain the health of the animal (Jiji Press, 2020). Belgium's potato industry had a similar issue, where they faced a negative demand shock from a fall in demand for processed potato products as fewer Belgians and tourists consume fries from local friteries and restaurants. With 75% of potatoes from Belgian potato farms grown to be processed into frozen potato products, there was a surplus of 750,000 tons of excess potatoes within months of lockdown (Taylor, 2020).

5.2. Supply Chain Resilience Strategies

Offline-to-Online

Given the circumstance of store closures and confinement measures, many businesses were unable to operate and sell their goods at physical stores. Companies with e-commerce platforms before the pandemic minimised the impact of lost sales by encouraging consumers to purchase goods online. Moreover, e-commerce became popular as consumers sought alternative methods such as home deliveries to minimise human-to-human contact to reduce transmission and infection. Prior to the pandemic, businesses such as L'Oreal, Decathlon, Walmart and Carrefour had online platforms offering home delivery services to their customers. Within Q1 of 2020, Walmart's e-commerce sales in the US rose by 74% (Walmart, 2020a) a few months into the pandemic as more consumers purchase groceries online. L'Oreal made online sales through Alibaba and JD (Reuters, 2020d), thereby offsetting most of their losses from physical stores. During the pandemic, L'Oreal's e-commerce segment grew by 52.6%, representing nearly 20% of total sales (L'Oréal, 2020). Such offline-to-online strategies have a long-term impact on the business as they can offer permanent alternative methods of purchase for consumers. These strategies involve high effort as they require regular capital investments as well as sufficient online volumes even prior to exceptional events such as COVID-19 to break-even or make profits (Karakaya and Stahl, 2009).

Product Portfolio Mix

Before the pandemic, some companies possessed a diverse product portfolio for various groups of consumers. The pandemic led to a demand surge for some products and services (e.g. medical products and indoor exercise equipment), as well as a dip in demand for other non-essentials (e.g. cosmetics and flight tickets). Companies with a mixed product portfolio mitigated the impact of lost sales from one segment with gained sales from another. L'Oreal's product portfolio encompasses a mix of beauty and skincare products, ranging from cosmetics such as NYX Cosmetics to dermatological products like La Roche-Posay. During COVID-19, the company experienced reduced demand for cosmetics as consumers stayed home. Conversely, consumers rushed for their cleansing products such as hand sanitiser and facial wipes, resulting in stockouts worldwide. Decathlon's product portfolio extended across 55 kinds of sports, from outdoor sports to indoor sports such as yoga. Similar to L'Oreal, Decathlon's customers were at home more often and thus demand for indoor exercise products rose as demand for outdoor sports products fell. Both companies were able to recoup some losses from some segments with gains from others. Diversifying portfolio product mix is a long-term and high-effort strategy, as it requires infrastructural changes and capital investments to introduce new products.

Strategic Facility Placement

Before COVID-19, some companies already had strategic facility placements to avoid the risk from movement restriction measures across borders. For instance, L'Oreal's manufacturing plants in Arkansas comprise 75% of what they sell in the US. This enables the company to continue serving the US market despite countries going to lockdown (Shiff, 2020). This strategy is high-effort for companies with an already established infrastructure worldwide as it requires a large amount of restructuring but has a long-term impact. However, effectiveness may be limited by regional lockdowns such that with movement restrictions, certain plants could only serve the immediate vicinity that the facilities are situated in, limiting the consumer pool the company could have accessed.

Stock Control

To reduce stockouts and lost sales, companies limited purchases in anticipation of high demand during COVID-19 to reduce hoarding by individual customers whilst ensuring sufficient supply for each customer. For example, CVS Health limited the purchase of COVID-19 related medication for each customer per purchase, providing as low as a 10-day supply of medication per customer with no refills (CVS Health, 2020). A counterpart to this strategy is the procurement and creation of strategic supply stockpiles *before* and in anticipation of the pandemic. Logistics SG began responding to the risk as news of the first COVID-19 cases at Wuhan (China) appeared in December 2019. By January 2020, before the first case of COVID-19 arrived in Singapore, the company was able to procure sufficient stock of medical items to support the demands of their client. They were able to avoid the supply shock of medical item shortages worldwide that came after April 2020, months later. Stockpiling involves low effort when employed before the risk event as it is easier for companies to procure goods while suppliers are still stocked and accessible. As stockpiles will eventually deplete, the strategy has a short-term impact and limited feasibility. Hence, stockpiling as a reactive strategy would be ineffective beyond the first wave of a pandemic. Moreover, stockpiling incurs the risk of surplus, unless the pandemic is predicted to last over a long period.

5.3. Supply Chain Risk Mitigation Strategies

Increasing Capacity

The most direct way to support a demand surge would be to increase production capacity during the risk event. GE Healthcare, CVS Health and Walmart responded to demand surges by hiring more manpower to support production and service. Walmart initiated "Project 24", which removed red tape to shorten hiring time from 3 weeks to 24 hours and hired more than 400,000 new associates, exceeding the initial goal of 150,000 within months (Walmart, 2020d). CVS likewise made plans to hire 50,000 people as a response to support their stores and warehousing needs (LaVito, 2020). Moreover, CVS increased capacity to support the rise in demand for COVID-19 tests by adding 1,900 test sites across the US at various locations (Reuters, 2020a). Similarly, GE hired more people in production to increase its manufacturing capacity for critical goods such as medical ventilators (Reuters, 2020b). Increasing production capacity is a high-effort strategy as it requires high cost for manpower and an increased effort in the hiring and training process that would occupy a substantial amount of resources. This strategy has a short-term impact as it is only intended to meet a demand surge during the risk event, as it has implications on excess capital and resources in the future.

Diversifying Single-Product Categories

During the COVID-19 pandemic, single-product companies expanded their product lines, to offset losses from products with low demand with the gains from those in higher demand. Shinrinno Farm minimised wastage and lost sales from unsold fresh milk by converting it to products with longer shelf life, such as cheese and butter (Shinrinno Farm, 2020b). They not only met the needs of their consumers but also enabled themselves to store their inventories for longer periods without spoilage. Similarly, Park N Parcel expanded its transport services from solely transporting goods to pick-up points, to offering home delivery services for regular consumers and online retailers, as well as regular operational transport services for large retailers such as Nature's Farm (Tan, 2020). This enabled Park N Parcel to offset lost demand for their pick-up point deliveries with that for the new services. Diversifying single-product categories is a high-effort, long-term impact strategy as it requires making major changes to its production and purchase infrastructure to accommodate new products or services. However, this strategy does not apply to all single-product businesses as not all goods can be further processed or repurposed. For instance, the processed potatoes in the Belgian potato industry were generally unsuitable to be consumed nor sold as fresh potatoes in grocery stores. As a result, 750,000 tons of processed potatoes were at risk of being disposed of, as the Belgian potato industry was unable to diversify its main produce.

Local Sourcing

With border restrictions for goods put in place during the pandemic, outsourcing and procurement of products and services became difficult and limited. To support their operations, companies turned to local businesses and suppliers. The grocery industry faced a demand surge for essential goods over COVID-19, resulting in stockouts. To meet demand given constraints, Walmart and Carrefour created marketplace platforms for local businesses to sell their products (Carrefour, 2020; Walmart, 2020b). This increased Carrefour and Walmart's product variety, offering customers alternate brands without having to overwhelm its warehouse capabilities as goods will be delivered directly from these businesses. Local sourcing is a low-effort strategy as it involves searching through a smaller supplier pool in the local vicinity and does not involve extensive changes to the infrastructure. This strategy creates a long-term impact as local sourcing increases supply chain resilience. However, the cost of local sourcing is generally less cost-effective compared to global sourcing (Niu et al., 2020). Thus, companies may consider a mix of local and overseas sourcing to diversify risks while balancing overall costs.

Prioritising Critical Categories

Companies with a mix of poor-performing and well-performing segments during the pandemic tended to focus on fulfilling outperforming products/categories. L'Oreal, GE and Logistics SG faced similar situations in which one customer segment was poor-performing whilst another faced an overwhelming demand during the COVID-19 pandemic. In response, these companies prioritised their critical categories. For example, L'Oreal focused on hand sanitiser production (Pays, 2020), whilst Logistics SG prioritised healthcare customers (Mishra, 2020). Similarly, companies with e-commerce capabilities focused on garnering and supporting online platform sales, as sales at their physical stores dwindled. Prioritising critical categories is a low-effort, short-term strategy as it only requires companies to change their focus onto a pre-existing category during the risk event to cope with the repercussions of the disruption.

Repurposing Assets

During COVID-19, many companies redeployed assets from poor-performing segments to support the overwhelming demand at better-performing segments. This increased these companies' capabilities in supporting demand and redirected resources to minimise waste. GE (the parent of GE Healthcare) repurposed assets from its aviation division to support the healthcare sector. Originally meant to manufacture power systems for aircraft, GE's Cheltenham factory was repurposed to install medical equipment accessories to support the surge in demand for patient monitors during the COVID-19 outbreak (GE, 2020b). Staff were re-trained, and the factory acquired basic equipment required to conduct the installation. Logistics SG similarly converted resources from sectors facing low demand to support the healthcare sector that faced a demand surge. The company repurposed transport vehicles and storage facilities to support its clients that distributed medical supplies to hospitals and those in need. Moreover, as more people were quarantined in Singapore, demand for ready-to-eat meals increased and thus Logistics SG helped its client re-purpose its inventory of unused food rations by re-assembling them to meet demand. Repurposing assets is a high-effort strategy that involves changes in standard operations and modification of current infrastructure to cater for the shift in production and service. Its impact is short-term, as re-purposed assets tend to be sub-optimally suited to fill long term needs.

Establishing Partnerships

The pandemic prompted many businesses to work together, leveraging each other's functions and capabilities to enhance their operations. Some companies worked with e-commerce platforms to reach out to their customers. L'Oreal worked with Lazada (an online shopping platform) to create the Bring Beauty Back campaign in June 2020 on Lazada's website to promote L'Oreal products (Reuters, 2020c). Similarly, Walmart worked with Shopify, another e-commerce platform to expand its capacity to support more customers and include more variety of goods from local businesses (Walmart, 2020b). Park N Parcel partnered with companies, such as Carousell and Unilever that faced demand surges but lacked transport capabilities, to offer home delivery services (Tan, 2020). GE Healthcare partnered with Ford Motor Company to “design and produce a simplified version of its existing ventilator that can be manufactured quickly” (GE, 2020a). Unlike supply chain integration or collaboration that are commonly advocated in the literature, partnerships as practiced by case companies were low-effort initiatives that used current complementary capabilities of companies to fill immediate needs, but such partnerships may potentially have long-term impact, as they set the foundations for more formal future collaborations.

Leveraging Social Media Influence

Leveraging a global surge in consumption of online content during COVID-19, companies such as in the agriculture industry took to social media to shape demand during the pandemic to raise awareness on the issues they faced. Shinrinno Farm started a project called SaveMilk to encourage their local community to purchase their products, encouraging social media users to spread the message “#SaveMilk”, as well as partnering with YouTubers to new desserts made using Shinrinno's milk products (Shinrinno Farm, 2020a). Similarly, the Belgian potato industry began a “SOSPatat” movement on social media to encourage Belgians to eat more fries and purchase more frozen potato products (Too Good To Go, 2020). Leveraging social media influence is a low-effort strategy as it saves on advertising costs by using the audience to spread the message (Dwivedi et al., 2020). However, its effectiveness is dependent on how it is implemented and how rapidly the demand-shaping initiatives can match changes in the supply chain.

5.4. Discussion of Key Findings

Based on the above contextualisation of the impact of the COVID-19 pandemic on companies and categorisation of businesses' responses towards managing such pandemic risks, the following key findings can be established.

First, *businesses were generally not well-prepared for the risks from a global pandemic*. The impact of the COVID-19 pandemic throughout 2020 showed that businesses' supply chain resilience was generally low, even if risk mitigation strategies implemented reactively showed more encouraging signs of effectiveness. A probable reason for the lack of resilience may lie in the fact that industries had not expected pandemic risks to create such a large extent of demand and supply shocks amid nationwide lockdowns (del Rio-Chanona et al., 2020), and thus did not prepare for them. Another possible reason is the rapid speed at which the economic effects (if not the public health effects) of the pandemic propagated from mega-cities to surrounding regions (Hiroyasu and Yasuyuki, 2020).

Second, *there is no universal strategy that can be employed in any company or industry*. Examination of the implemented solutions found that there is no one-size-fits-all strategy that can be applied to any company, since each strategy has its own strengths and limitations. For instance, it would be disadvantageous to employ stockpiling if it creates a greater (and more costly) risk of a surplus. Likewise, businesses seeking a long-term strategy to mitigate a high-impact event would not find it beneficial to implement short term strategies designed to mitigate a low-impact high-frequency event (Namdar et al., 2017). Moreover, strategies requiring intensive capital changes may be prohibitive for small and/or low-margin businesses, for which generic strategies such as bricolage could be more valuable (Ketchen and Craighead, 2020). These highlight the usefulness of risk management frameworks in aiding companies employ suitable strategies in a pandemic event. Furthermore, although the nature and extent of impact of the pandemic on individual businesses varied greatly, it can be observed that the *type of industry* plays little part on the type of strategies implemented and there were no distinct strategies unique to a single industry. For instance, partnership was employed in all the industries that we studied, which suggests that companies should not necessarily be constrained by the type of industry when selecting suitable pandemic risk management strategies.

Third, *each company employed more than one strategy towards handling disruptions from the COVID-19 pandemic*. For instance, GE Healthcare employed at least six strategies to mitigate COVID-19, with varying degrees of efficacy in terms of increasing medical ventilator production to meet consumer demand. Other companies examined in this study also implemented multiple strategies against the COVID-19 pandemic. In some cases, such a multi-pronged approach appears to have been adopted not necessarily in a systematic manner, but rather as part of a portfolio of

existing strategies that were activated to mitigate unknown-unknown risks as well as new reactive strategies that were developed out of necessity. This suggests that identification, assessment, mitigation and control of risks (El Baz and Ruel, 2020) should be part of a continuous decision process by supply chain managers.

Fourth, *partnership was the most frequently employed strategy by companies*, whereby companies partnered with others to increase their own capacity or “borrowed” others’ capabilities to perform tasks that they were unable to. Our findings show that all five industries studied employed partnerships as a reactive strategy. Other than a little “entrepreneurial orientation” (Ketchen and Craighead, 2020), fostering partnerships involves relatively low effort and cost. Yet, it may have a long-term impact by increasing connectivity and network size (Dixit et al., 2020). Moreover, partnerships can promote information sharing, which enhances long-term resilience (Li et al., 2016; Kumar and Anbanandam, 2019).

5.5. COVID-19 Risk Management Frameworks

The above findings suggest that the use of decision frameworks can aid companies in selecting appropriate strategies for implementation. The choice of strategies would depend on the impact on business and the degree of responsiveness to a risk event. Furthermore, firms would be concerned with degree of effort and cost required as well as the duration of impact that a particular strategy would have. Consequently, two frameworks have been synthesised to aid companies in making decisions towards employing the appropriate strategies to manage pandemic risk, depending on the contextual factors in a given scenario.

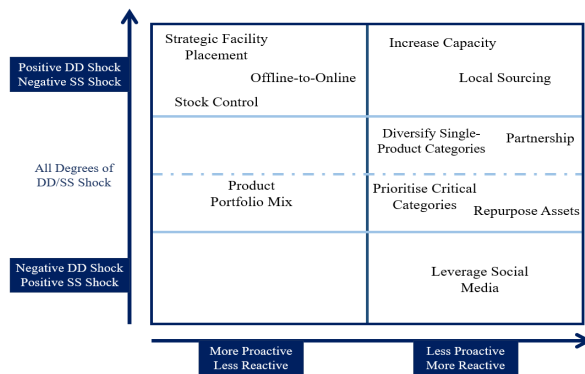


Figure 2. Shock-Responsiveness Framework

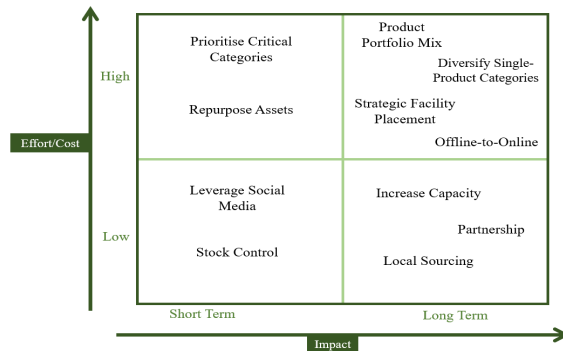


Figure 3: Effort-Impact Framework

As shown in Figure 2, the Shock-Responsiveness Framework arranges strategies based on demand/supply shocks against the degree of responsiveness in relation to a pandemic risk event. As our literature review shows, demand and supply shocks may be inversely related or even lead to vicious cycle, whereby a positive demand shock is followed by a negative supply shock and vice versa. Thus, both demand shock and supply shock have been grouped in a single vertical axis in the framework. The degree of responsiveness comprises of two extremes – Proactive and Reactive. Proactive refers to employing SCR measures against the risk before the actual event. Reactive refers to employing SCRM measures against the risk in response to the occurrence of the risk itself. With a similar inverse relationship for demand shock and supply shock, proactivity and reactivity have been grouped as a single horizontal axis in the framework. Various strategies are able to tackle both positive and negative demand and supply shock. The framework recognises this by classifying these strategies in the middle of the framework. For example, repurposing assets can mitigate both demand and supply shocks, but would be of a reactive nature. On the other hand, while long international supply chains are often unavoidable in a regular, non-pandemic environment, the ability to switch rapidly to local sourcing at the onset of a supply shock could be very effective in securing supplies in the immediate vicinity by avoiding transport network disruptions that could result from movement controls.

The Effort-Impact Framework in Figure 3 arranges strategies according to the cost and effort required to implement a strategy against the duration of impact of each strategy. From Sections 5.2 and 5.3, it can be observed that risk management strategies vary in terms of the degree of effort required. Some strategies require little effort and cost to implement, whereas others require more effort and cost as they involve more drastic changes to the company's regular operations. The degree of change is represented on the vertical axis. In addition, some strategies' effects last for a shorter period relative to other strategies'. The duration of impact is represented on the horizontal axis. For example,

building a broad product portfolio mix is a long-term impact endeavour and in some industries may require significant amounts of research and development, but would likely have one of the greatest impacts on the resilience of a business.

6. Conclusion

The COVID-19 pandemic impacted companies worldwide through a combination of demand and supply shocks (del Rio-Chanona et al., 2020), hampering economic growth while devastating companies' performances. However, many companies overcame disruptions by employing proactive and reactive supply chain risk management strategies to sustain their businesses. This research offered perspectives and insights from five industries, based on a comparative case approach (Bartlett and Vavrus, 2016). This paper has identified eleven strategies that companies across a broad spectrum had employed to fortify their supply chains prior to and during the COVID-19 pandemic. The strategies have been classified under SCR and SCRM, which can be generalised to refer to "proactive" and "reactive" strategies respectively. This study has contributed to the body of research on COVID-19 risk management by developing two contingency and typology frameworks – the Shock-Responsiveness and Effort-Impact Frameworks – to aid companies in determining suitable types of risk management strategies to minimise the impact of pandemic risks. We thus follow the call of DuHadway et al. (2017) on the need to create a framework segregating the risk at different stages around the risk event. At the time of writing, the COVID-19 pandemic was still ongoing. As a result, it is as yet difficult to fully determine the effectiveness of each strategy identified in this study until more time has passed. Moreover, this study has not studied post-pandemic recovery strategies that companies can employ. Thus, future studies may seek to further examine recovery strategies and evaluate the effectiveness of these strategies to enhance the current knowledge of supply chain risk management in preparation for future pandemics.

References

- Annarelli, A., & Nonino, F. (2016). Strategic and operational management of organizational resilience: Current state of research and future directions. *Omega*, 62, 1–18.
- Baker, S., Farrokhnia, R. A., Meyer, S., Pagel, M., & Yannelis, C. (2020). How Does Household Spending Respond to an Epidemic? Consumption During the 2020 COVID-19 Pandemic. *NBER Working Paper Series*, 1–35.
- Bartlett, L., & Vavrus, F. (2016). *Rethinking case study research: A comparative approach*. 1st Edition, Taylor & Francis, New York.
- Biesemans, B. C. L. (2020). *Do your bit for farmers and eat more fries, Belgians urged*. Reuters. <https://www.reuters.com/article/us-health-coronavirus-belgium-potatoes-idUSKBN22B2NT>
- Carrefour. (2020). *Carrefour launches its food marketplace*. Carrefour Group. <https://www.carrefour.com/en/newsroom/carrefour-launches-its-food-marketplace>
- CVS Health (2020). Our actions in response to COVID-19, <https://cvshhealth.com/covid-19/cvs-health-actions>
- del Rio-Chanona, R. M., Mealy, P., Pichler, A., Lafond, F., & Farmer, D. (2020). Supply and demand shocks in the COVID-19 pandemic: An industry and occupation perspective. *Oxford Review of Economic Policy*. Aug 2, 1–44.
- Dixit, V., Verma, P., & Tiwari, M. K. (2020). Assessment of pre and post-disaster supply chain resilience based on network structural parameters with CVaR as a risk measure. *International Journal of Production Economics*, 227, 1–17.
- DuHadway, S., Carnovale, S., & Hazen, B. (2017). Understanding risk management for intentional supply chain disruptions: risk detection, risk mitigation, and risk recovery. *Annals of Operations Research*, 283(1–2), 179–198.
- Dwivedi, Y. K., Ismagilova, E., Hughes, D. L., Carlson, J., Filieri, R., Jacobson, J., Jain, V., Karjaluo, H., Kefi, H., Krishen, A. S., Kumar, V., Rahman, M. M., Raman, R., Rauschnabel, P. A., Rowley, J., Salo, J., Tran, G. A., & Wang, Y. (2020). Setting the future of digital and social media marketing research: Perspectives and research propositions. *International Journal of Information Management*, 102168.
- Eisenhardt, K. M., & Graebner, M. E. (2007). Theory Building From Cases: Opportunities And Challenges. *Academy of Management Journal*, 50(1), 25–32.
- El Baz, J., & Ruel, S. (2020). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *International Journal of Production Economics*, 107972.
- Farrell, H., & Newman, A. (2020). *Will the Coronavirus End Globalization as We Know It?* Foreign Affairs. <https://www.foreignaffairs.com/articles/2020-03-16/will-coronavirus-end-globalization-we-know-it>
- GE. (2020a). *All Hands On Deck: Volunteers Rush In To Support 24/7 Production Of Ventilators In Wisconsin* | GE News. General Electric. <https://www.ge.com/news/reports/all-hands-on-deck-volunteers-rush-in-to-support-24-7-production-of-ventilators-in-wisconsin>

- GE. (2020b). *Lean Management Is Driving GE's Turnaround. It's Also Helping During The COVID-19 Pandemic | GE News*. <https://www.ge.com/news/reports/lean-management-driving-ge-turnaround-it-is-also-helping-during-covid-19-pandemic>
- GlobalData. (2020). *Ventilator crisis during coronavirus outbreak as over 880,000 are needed*. <https://www.globaldata.com/ventilator-crisis-during-coronavirus-outbreak-as-over-880000-are-needed/>
- Guerrieri, V., Lorenzoni, G., Straub, L., & Werning, I. (2020). Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages? *SSRN Electronic Journal*, 1–37.
- Hiroyasu, I., & Yasuyuki, T. (2020). The Propagation of the Economic Impact through Supply Chains: The Case of a Mega-City Lockdown against the Spread of COVID-19. *SSRN Electronic Journal*, 1–11.
- Hodkinson, P., & Hodkinson, H. (2001). The strengths and limitations of case study research. *Presented to the Learning and Skills Development Agency Conference: Making an Impact on Policy and Practice*, 1–13. https://www.academia.edu/31677978/The_Strengths_and_Limitations_of_Case_Study_Research
- International Monetary Fund. (2020, June 24). *World Economic Outlook Update, June 2020: A Crisis Like No Other, An Uncertain Recovery*. <https://www.imf.org/en/Publications/WEO/Issues/2020/06/24/WEOUpdateJune2020>
- Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International Journal of Production Research*, 58(10), 2904–2915.
- Jiji Press. (2020). *Japanese Dairy Farmers in Bind amid Virus Crisis*. Nippon. <https://www.nippon.com/en/news/yjj2020042900458/>
- Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics Research and Applications*, 6(4), 197–210.
- Kamerow, D. (2020). Covid-19: the crisis of personal protective equipment in the US. *BMJ*, 369, m1367.
- Karakaya, F., & Stahl, M. J. (2009). After Market Entry Barriers in E-Commerce Markets. *Journal of Electronic Commerce Research*, 10(3), 130–143.
- Kırılmaz, O., & Erol, S. (2017). A proactive approach to supply chain risk management: Shifting orders among suppliers to mitigate the supply side risks. *Journal of Purchasing and Supply Management*, 23(1), 54–65.
- Ketchen Jr, D. J., & Craighead, C. W. (2020). Research at the Intersection of Entrepreneurship, Supply Chain Management, and Strategic Management: Opportunities Highlighted by COVID-19. *Journal of Management*, 46(8), 1330–1341.
- Kumar, S., & Anbanandam, R. (2019). Impact of risk management culture on supply chain resilience: An empirical study from Indian manufacturing industry. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, 234(2), 246–259.
- LaVito, A. (2020). *CVS Health to Hire 50,000 in Response to Coronavirus Demand*. Bloomberg. <https://www.bloomberg.com/news/articles/2020-03-23/cvs-health-to-hire-50-000-in-response-to-coronavirus-demand>
- Lee, D. (2020). *Coronavirus: Fitness equipment in hot demand as "circuit breaker" brings sports to a halt*. The Straits Times. <https://www.straitstimes.com/sport/coronavirus-fitness-equipment-in-hot-demand-as-circuit-breaker-brings-sports-to-a-halt>
- Li, Y., Zobel, C. W., Seref, O., & Chatfield, D. (2020). Network characteristics and supply chain resilience under conditions of risk propagation. *International Journal of Production Economics*, 223, 107529.
- Light, J., Mider, Z., & Proper, E. (2020). *Ventilator Makers Can Speed Up But Face Shortages of Parts*. Bloomberg. <https://www.bloomberg.com/news/articles/2020-03-24/ventilator-makers-can-speed-up-but-they-face-shortages-of-parts>
- Litton, E., Bucci, T., Chavan, S., Ho, Y. Y., Holley, A., Howard, G., Huckson, S., Kwong, P., Millar, J., Nguyen, N., Secombe, P., Ziegenfuss, M., & Pilcher, D. (2020). Surge capacity of intensive care units in case of acute increase in demand caused by COVID -19 in Australia. *Medical Journal of Australia*, 212(10), 463–467.
- L'Oréal. (2020). *First Quarter 2020 Sales*. L'Oréal Finance. <https://www.loreal-finance.com/eng/news-release/first-quarter-2020-sales>
- Manhart, P., Summers, J. K., & Blackhurst, J. (2020). A Meta-Analytic Review of Supply Chain Risk Management: Assessing Buffering and Bridging Strategies and Firm Performance. *Journal of Supply Chain Management*, 56(3), 66–87.
- Meyersohn, N. (2020). *CVS warns there could be a shortage of hand sanitizer*. CNN. <https://edition.cnn.com/2020/02/28/business/hand-sanitizers-wipes-cvs-walgreens-coronavirus/index.html>
- Mishra, M. (2020). *GE Healthcare to produce ventilators round-the-clock to meet coronavirus-led demand*. Reuters. <https://www.reuters.com/article/us-health-coronavirus-ge/ge-healthcare-to-produce-ventilators-round-the-clock-to-meet-coronavirus-led-demand-idUSKBN2161TW>

- Namdar, J., Li, X., Sawhney, R., & Pradhan, N. (2017). Supply chain resilience for single and multiple sourcing in the presence of disruption risks. *International Journal of Production Research*, 56(6), 2339–2360.
- Nikolopoulos, K., Punia, S., Schäfers, A., Tsinopoulos, C., & Vasilakis, C. (2020). Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions. *European Journal of Operational Research*. In-Press
- Niu, B., Xie, F., Mu, Z., & Ji, P. (2020). Multinational firms' local sourcing strategies considering unreliable supply and environmental sustainability. *Resources, Conservation and Recycling*, 155, 104648.
- Pays, C. (2020). *The beauty industry is rallying to fight Covid-19*. Vogue Paris. <https://www.vogue.fr/beauty-tips/article/lvmh-loreal-beauty-companies-producing-hand-sanitizer-to-help-hospitals>
- Reuters. (2020a). *CVS expands third-party lab partners network to speed up COVID-19 test results*. <https://www.reuters.com/article/health-coronavirus-cvs-health-testing/cvs-expands-third-party-lab-partners-network-to-speed-up-covid-19-test-results-idINL4N2FM2PU>
- Reuters. (2020b). *GE Healthcare Says Hiring More Manufacturing Employees And Moving Current Employees to Support Increased Demand*. <https://www.reuters.com/article/brief-ge-healthcare-says-hiring-more-man/brief-ge-healthcare-says-hiring-more-manufacturing-employees-and-moving-current-employees-to-support-increased-demand-idUSFWN2BC0XF>
- Reuters. (2020c). *L'Oréal Banks on Post-Lockdown Rush to Hair Salons*. The Business of Fashion. <https://www.businessoffashion.com/articles/news-analysis/loreal-banks-on-post-lockdown-rush-to-hair-salons>
- Reuters. (2020d). *L'Oréal's online sales of make-up rose in China in February: CEO*. <https://www.reuters.com/article/us-china-health-loreal-idUSKBN20F23A>
- Shiff, B. (2020). *Coronavirus "not bothering" L'Oréal supply chain, CEO says*. Fox Business. <https://www.foxbusiness.com/lifestyle/coronavirus-loreal-supply-chain>
- Shinrinno Farm. (2020a). *SaveMilk Project*. SaveMilk. <https://savemilk.net/>
- Shinrinno Farm. (2020b). *Store*. 森林ノ牧場. <https://www.shinrinno.jp/store/>
- Singh, S., Kumar, R., Panchal, R., & Tiwari, M. K. (2020). Impact of COVID-19 on logistics systems and disruptions in food supply chain. *International Journal of Production Research*, 1-16. In-Press
- Tan, S. (2020). *SMEs adapt to meet changing demands resulting from coronavirus*. The Straits Times. <https://www.straitstimes.com/business/economy/smes-adapt-to-meet-changing-demands-resulting-from-virus>
- Taylor, C. (2020). *Belgians urged to eat fries twice a week as coronavirus creates massive potato surplus*. CNBC. <https://www.cnbc.com/2020/04/28/coronavirus-belgians-urged-to-eat-fries-twice-a-week-during-lockdown.html>
- The Straits Times. (2020). *"Drink more milk": Japanese official pleads in cow costume as dairy industry struggles*. <https://www.straitstimes.com/asia/east-asia/drink-more-milk-japanese-official-pleads-in-cow-costume-as-dairy-industry-struggles>
- Too Good To Go. (2020). *SOSPatat Movement*. SOSPatat. <https://www.sospatat.be/>
- Walmart. (2020a). *Walmart Corporate - Q1 FY21 Earnings Release*. https://corporate.walmart.com/media-library/document/q1-fy21-earnings-release/_proxyDocument?id=00000172-29ed-d3ff-a3f6-bded2c350000
- Walmart. (2020b). *Walmart Expands Its eCommerce Marketplace to More Small Businesses*. <https://corporate.walmart.com/newsroom/2020/06/15/walmart-expands-its-ecommerce-marketplace-to-more-small-businesses>
- Walmart. (2020c). *Walmart Investor Relations - Investors - Financial Information - Unit Counts & Square Footage*. Walmart. <https://stock.walmart.com/investors/financial-information/unit-counts-and-square-footage/default.aspx>
- Walmart. (2020d). *How Walmart Mobilized to Hire Hundreds of Thousands During a Pandemic*. Walmart Corporate - US. <https://corporate.walmart.com/facing-the-outbreak/new-hires>
- World Health Organisation. (2020). *Situation reports*, August 1 <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports>
- Yin, R. K. (2017). *Case Study Research and Applications*, 6th Edition, SAGE Publications, Los Angeles.

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