DEVELOPING AN ANALYTICAL FRAMEWORK TO DEPICT DISRUPTIONS IN THE PHARMACEUTICAL SUPPLY CHAIN DURING COVID-19: A SCOPING REVIEW

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ABSTRACT: The COVID-19 pandemic impacted the pharmaceutical supply chain (PSC) globally. As a result, consumers, pharmaceutical industries, and retailers have been facing supply chain disruptions since 2020. This paper aims to identify the causes and effects of PSC disruptions through a scoping review and propose an analytical framework for further study in Australia and overseas. This scoping review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Based on inclusion/exclusion criteria, 47 full articles were included in this review. Studies show significant disruptions to PSC where important contributing factors include: (i) reduction in product supply due to production disruptions and border closures, (ii) increased demand for healthcare products and, (iii) changes in consumers' purchasing behaviour. The study developed an analytical framework that can

systematically be used to map PSC disruption in regional settings in Australia and overseas.

KEYWORDS: COVID-19; supply chain disruption; pharmaceutical supply chain; Australian pharmaceutical supply chain; supply chain resilience.

1. INTRODUCTION

Supply chain management (SCM) consists of a series of operations that occur to supply commodities from producers to end-users (Okeagu *et al.*, 2021). It is a chain of operations and distribution process that procures resources, manufactures them into outputs, and delivers them to clients. For the delivery of medicines, SCM is critical, because the quality of healthcare delivery is contingent on timely access to medical supplies in the right quantity to the patient. Healthcare commodity supply chain is an important component of a well-functioning health system for achieving national and regional healthcare outcomes and fostering trust in healthcare delivery systems. The healthcare supply chain is distinct from the manufacturing supply chain in terms of the degree of customised services given, the level of involvement of a partner or consumer, and the inherent unpredictability in the fundamental processes (Mathur *et al.*, 2018).

The Coronavirus (COVID-19) has impacted global supply chain networks, causing supply chain disruptions (SCD) in the pharmaceutical supply chain (PSC), when supply falls significantly short of demand (Okeagu *et al.*, 2021). Such breakdowns occur when a business process's conventional supply capacity is severely reduced for an extended period, or when demand spikes unexpectedly due to availability uncertainty. This occurred in panic buying and stockpiling at the start of the pandemic, including lockdowns and border closures, due to which supply chains were disrupted by manufacturing, logistics, and transportation services (Friday *et al.*, 2021).

The pandemic had a significant impact on worldwide PSC systems, reducing the availability of essential medicines in both public and private health institutions (Tirivangani *et al.*, 2021). These issues have impacted the availability and accessibility of pharmaceutical items in many regional towns and cities around Australia, notably in regional Queensland, causing SCD. On the other hand, some disruptions could be minimised by using

better transport and logistics services and utilizing human factor engineering in the production system (Friday *et al.*, 2021). However, these PSC services would cost much more than the standard logistics and transport services used. In such a scenario a systematic study to identify the important determinants influencing PSC in regional Queensland is required.

The study's potential significance lies in its aim to develop an analytical framework for depicting disruptions in the PSC during pandemic situations similar to COVID-19. Shortage of pharmaceutical goods in the local pharmacies in regional Queensland is a key issue of the study. This shortage is because Australia relies largely on imports of medicines and has minimal local production (Bozorgi and Fahimnia, 2021). In Australia, these essential supplies are predominantly procured through an extensive and intricate supply chain, and roughly 68% of the country's medical imports are derived from the United States (US) and Europe. These in turn rely on a supply of active pharmaceutical ingredients (API), chemicals and componentry from India, China, and other countries. Due to the limited domestic production capability of $4.9 billion in value, the majority of its medical supplies are imported at a cost of $16.6 billion each year (Butler and Sorrell, 2020). Australia had 463 current medication shortages as of October 27, 2020, and the rate of medicine outages rose by 300% between 2019 and 2020 (Cameron and Bushell, 2021). As a result, domestic production's incapability to meet the demand is a dominant driver in PSC disruption.

Consequently, Australia has significant impacts on PSC during the COVID-19 pandemic because of imposing limitations on air transportation, closing borders, preventing raw material delivery, manpower shortage and completely shutting down manufacturing operations (Chowdhury *et al.*, 2021). As a result, the retailing pharmaceutical sector was severely impacted by the pandemic's interrupted logistic and distribution routes specially in regional towns in Queensland, Australia. On the other hand, to maintain product availability in a sustainable manner while minimising disruption effects, PSC needs to implement alternative distribution channel measures that ensure the timely delivery of products to the retail segment, so that essential medicines are available to customers during the pandemic (Armani *et al.*, 2020; Ivanov 2020; Paul and Chowdhury, 2020).

Therefore, a pandemic-resilient PSC is required to revive Australia's pharmaceutical sector to boost its position, strengthen the resilience of its local supply chain, and deliver long-term health, and economic security.

2. THEORETICAL DOMAIN

The focus of this paper is to identify the effects and factors of PSC disruptions by developing an analytical framework for an efficient PSC during pandemic. Resource-based Theory (RBT) and Transaction Cost Theory (TCT) serve as the foundation to achieve the study objectives.

Resource-Based Theory

To be competitive and optimal, firms adopt various efficient and effective strategies. The goal is to lower the production costs of final goods and services by acquiring resources and capabilities from various businesses and stakeholders. This, in turn, enables the creation of economic value, achieving optimal output at the lowest production cost, and generating economic returns for shareholders (Barney *et al.*, 2021).

Transaction Cost Theory

Transaction Cost Theory (TCT) is concerned with the allocation of economic activity across alternative modes of organization such as firms and markets. TCT is a theory of efficient governance of transactions and exchange relationships in general to minimise the transaction cost (Williamson, 1985). It is one of the most widely used theories in operations and supply chain management research, as to how firms manage supply chain decisions.

3. REVIEW METHOD

This study aimed to develop an analytical framework for depicting disruptions in PSC during COVID-19. To meet the aim of the study, a scoping literature review was undertaken that compiled, evaluated, and synthesised the findings, main agreements and disagreements and knowledge gaps of prior research.

Scope and Analytical Framework of the Literature Review

To find relevant publications, different research databases (e.g. Scopus, Google Scholar, and ResearchGate) have been used with the keywords "Supply chain management", "COVID-19", "Pharmaceutical supply chain", "Supply chain disruptions", and "Supply chain cost". Original publications and narrative/systematic reviews that met the following

criteria were included for the years 2000-2022: i) examining impacts of SCD during a pandemic, ii) pharmaceutical supply chain management and disruptions during a pandemic, and iii) supply chain resilience. Studies on i) SCD in the manufacturing segment, ii) supply chain finance, and iii) papers other than English have been excluded from this review.
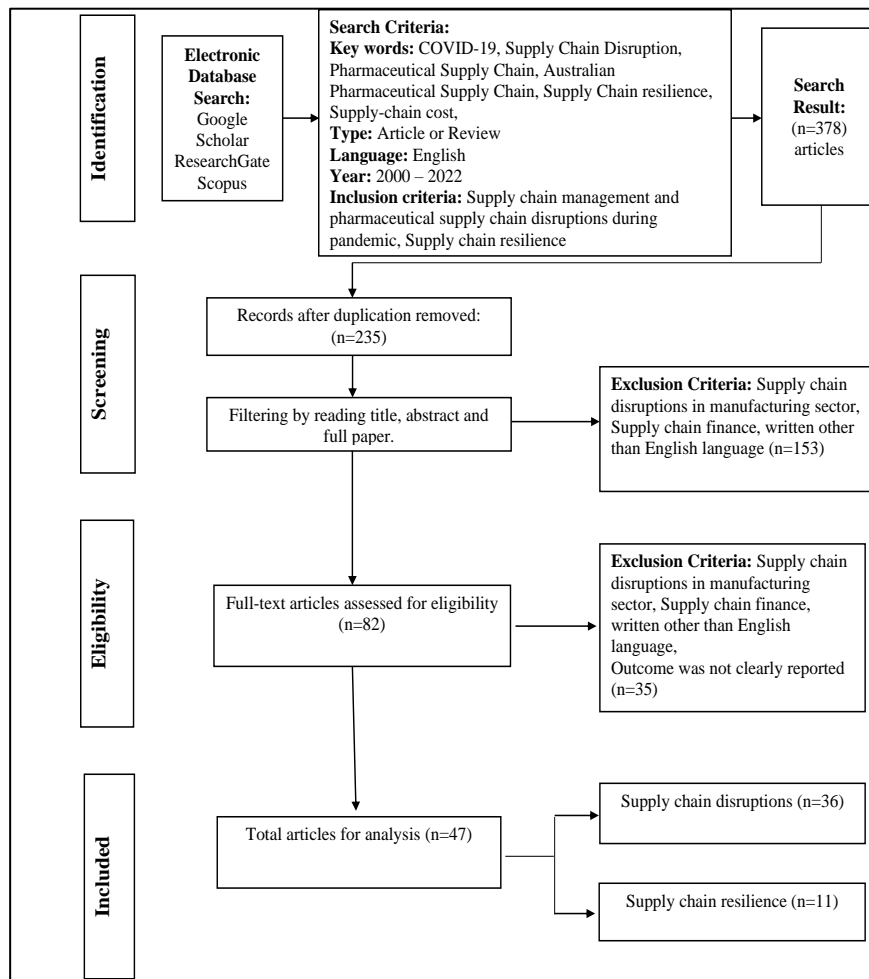

Figure 1. Literature Search Framework Using PRISMA Flow Diagram.
Source: Moher *et al.* (2009).

Figure 1, Illustrates the keywords searched in electronic databases that led to the discovery of 378 articles in total. After eliminating duplicate

articles, 235 articles remained for screening. The irrelevant results were further eliminated by reading titles, abstracts, and papers; this method resulted in the exclusion of 153 publications. As per the abstract review, 82 publications satisfied the criteria for inclusion and evaluation. Of these, 35 articles were eliminated based on exclusion criteria because the findings were not clearly documented. Finally, 47 publications were selected for the review process. These papers were studied methodically to summarise the findings as well as other factors such as the techniques, settings, and theories employed. The articles were methodically synthesised and summarised under three broad themes:

1. Pharmaceutical supply chain and the current practice in Australia
2. Supply chain disruptions
3. Efficient supply chain procedures

Defining Pharmaceutical Supply Chain and the Current Practice in Australia

Supply Chain Management:

"Supply Chain Management (SCM) is the process of integrating critical business operations from the end-user to the original suppliers in order to deliver products, services, and information that add value to consumers and other stakeholders" (Mathur *et al.*, 2018, p. 3). Torkabadi and Mayorga (2017) discussed the importance of quality control, and just-in-time (JIT) manufacturing for successful SCM. Further, Mathur *et al.* (2018) evaluated the total supply chain's effectiveness and verified six SCM parameters which included customer relationships, strategic supplier relationships, information quality, information exchange, postponement, and internal lean strategies. Therefore, during the pandemic situation, SCM in terms of just-in-time delivery of pharmaceutical goods provides quality healthcare services to the end-user consumers.

Pharmaceutical Supply Chain Management (PSCM):

Management of the Healthcare Supply Chain (HCSC) has gained increased attention from academics, professionals, and governments (Friday *et al.*, 2021). The healthcare supply chain has few internal components, whereas the commercial supply chain involves many external partners (Kwon *et al.*, 2016). Reliable and strong related supply chains enhance healthcare outcomes and foster trust in healthcare delivery

systems (Mathur *et al.*, 2018). PSCM is critical to the delivery of medicines. This is because patient access to medical supplies at the time of necessity and in adequate quantity is critical to the quality of healthcare delivery.

Supply-chain disruptions can bring customer dissatisfaction in case of shortage (Paul and Chowdhury, 2020). In a typical supply chain, there are numerous parties involved at various points along the value chain. In general, the HCSC has the same basic structure as other industries' supply chains. It is made up of input, process, and output with material and information flowing along the chain (Kritchanchai, 2014). Figure 2 shows the typical PSC framework for essential medicine.
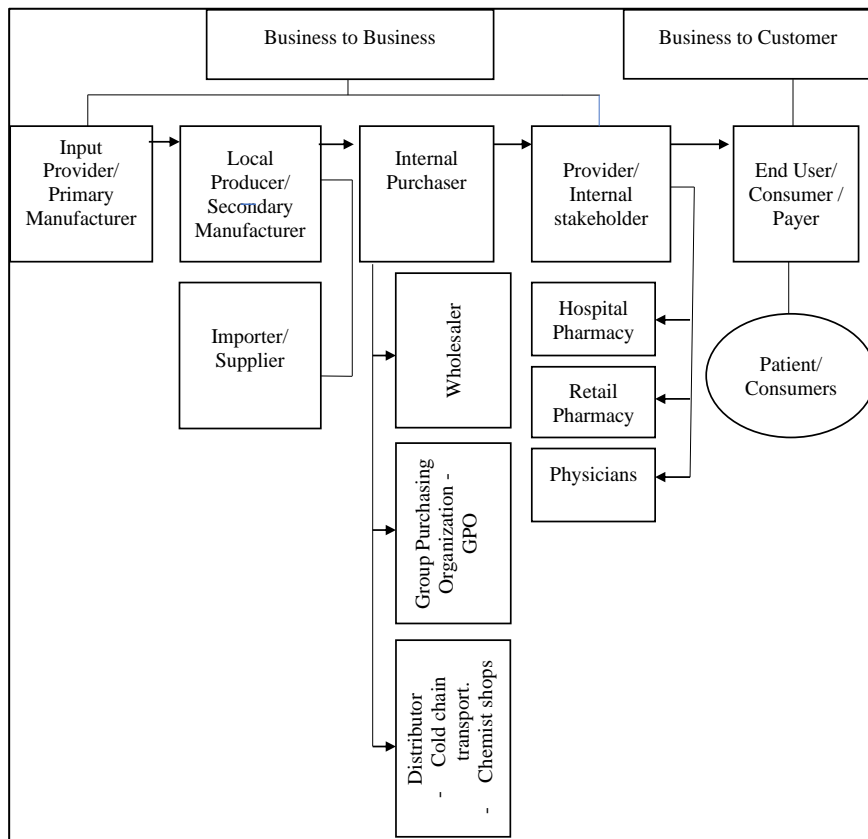

Figure 2. PSC Framework - Developed for this Study. Source: Adopted from Kritchanchai (2014) and Mathew *et al.* (2013).

Four types of players are identified by Mustaffa and Potter (2009) - (i) manufacturers including local producers and importers, (ii) distributors, (iii) healthcare providers, and (iv) consumers; and two types of manufacturers: (i) Primary manufacturer is an input provider involved in the creation of the active pharmaceutical ingredients (API) found in medications (ii) Secondary manufacturers are responsible for converting input into usable drugs like capsules, tablets, and other health/hygiene products. Manufacturers exert influence over pharmaceutical prices by assessing anticipated demand, potential competition, and project marketing costs (Kritchanchai, 2014). Distributors, wholesalers, and group purchasing organizations as internal purchasers, distribute the finished products to healthcare providers/internal stakeholders - hospital pharmacies, retail pharmacies and physicians (Kritchanchai, 2014). Finally, the patient/consumer is the ultimate user of the product, having paid for it and deriving consumer utility from the products.

The pharmaceutical supply chain in Australia: status-quo:

Significant national crises put pressure on the PSC, especially because Australia relies largely on imports with minimal domestic production (Bozorgi and Fahimnia, 2021). Butler and Sorrell (2020) have identified that over 68% of medical goods in Australia are imported from the United States and Europe. They, in turn, rely on India, China, and other countries for API, chemicals, and componentry. Another study by Cameron and Bushell (2021) revealed the fact that Australia had experienced 463 medication shortages as of October 27, 2020, with a 300% increase in the rate of medicine shortages between 2019 and 2020. Addressing these challenges will require a concerted effort to strengthen Australia's pharmaceutical sector, enhance its position in the global value chain, bolster local supply-chain resilience, and provide health, economic, and security benefits in the medium to long term (Butler and Sorrell, 2020). In certain circumstances, this may entail repurposing current drugs' safety stockpiles, obtaining components from different parts of the country, or establishing other manufacturing operations, and finding adequate clinical alternatives (Bozorgi and Fahimnia, 2021).

Pharmaceutical Supply Chain Disruption During the Pandemic

Supply chain disruption (SCD):

As global supply networks become more complicated and unpredictable, SCD is becoming more common. The most common causes of SCD are man-made threats (e.g. fires, strikes, and terrorism), natural disasters (e.g. epidemics, pandemics, earthquakes, hurricanes, and floods), and severe legal interruptions (Xu *et al.*, 2020). Several studies have focused on the advancement of management and logistical operations in an epidemic outbreak and designed alternative models for selecting the best local health agencies to conduct the immunization program (Dasaklis *et al.*, 2012; Syahrir and Vanany, 2015).

Pharmaceutical supply chain disruption:

When conventional supply chains are disrupted, corporations often lose income and market share, but interruptions in pharmaceutical related HCSCs can jeopardize the lives of thousands of men, women, children, and senior people as the demand for medical and healthcare services often increases. Rapid attention to the medical requirements of victims is stressed in disaster mitigation measures for the rescue and recovery scenario. Transport of products and services, as well as the purchase of commodities and supplies, are critical aspects in properly managing disaster support (Syahrir and Vanany, 2015). Rahman *et al.* (2020) investigated the effects of uncertainties in 208 retail drug stores' inventory management in Bangladesh due to the pandemic. The findings of their study revealed five factors responsible for the inventory management disruptions: (i) improved inventory management, (ii) market syndicate and price hikes, (iii) easier online purchase, (iv) delayed delivery, and (v) supply shortage.

Therefore, it becomes necessary to respond quickly and address the demand for medications as the outbreak advances to avoid deaths and suppress an epidemic spread using pharmacological logistic operations (Dasaklis *et al.*, 2012). There are still a few researchers who focus on unexpected conditions, such as in disaster-related crisis situations (Gunessee and Subramanian, 2020). As a result, developing a structured supply-chain framework can deal with obtaining and distributing medical supplies to consumers affected by supply disruptions.

Impact of COVID-19 as supply chain disruption:

A pandemic or epidemic can have serious effects on supply networks, including decreased efficiency and performance, causing ripple effects and shocks across supply networks, affecting their sustainability (Chowdhury *et al.*, 2021; Ivanov, 2020; Ivanov and Dolgui, 2021). Qin *et al.* (2021) examined the influence of COVID-19 and healthcare costs on Global supply chain and demonstrated a significant negative effect of health expenditure on it.

Unlike earlier epidemics, this pandemic affected all supply-chain nodes and linkages concurrently due to border closures, lockdowns, manpower shortages, disruptions in vehicle movements and international business, and social distancing (Chowdhury *et al.*, 2021; Gunessee and Subramanian, 2020; Paul and Chowdhury, 2020) consequently affecting the supply chain flow which triggered high demand essential items like personal protection equipment (PPE), ventilators, lifesaving drugs in both public and private health institutions (Tirivangani *et al.*, 2021).

Consumers reaction towards supply chain disruptions:

Due to the current COVID-19 outbreak, panic buying of both essential and non-essential products such as food, medication, and ventilators has been common (Iyengar *et al.*, 2020). The reasons behind panic buying and increased demand by the customers during COVID-19 outbreak include perceived dangers, behaviour imitation, future uncertainty, stockpiling tendencies, and other socio-psychological elements (Chowdhury *et al.*, 2021; Yuen *et al.*, 2020). Some studies accused shoppers of buying critical items too early, causing increased prices, out-of-stock items, and long lines at businesses. Thus, two complementary variables caused SCD: (i) supply shortage owing to manufacturing restrictions, and (ii) customers' erratic purchase patterns.

Efficient Pharmaceutical Supply Chain Procedure

Supply chain risks and resilience:

Failure to manage SCD risks can have adverse consequences on operational and financial performance (Hohenstein *et al.*, 2015). The dynamic economic climate and the increasingly complex and uncertain global supply-chain systems are posing a larger threat of catastrophic disruption than domestic supply chains. As a result, research on managing

risk and contingency planning to develop a robust SCM has gained prominence. Safa *et al.* (2021) analysed supply-chain risk in the field of healthcare supplies through the construction of an information-driven model of readiness, risk, reaction, and recovery.

According to Hohenstein *et al.* (2015), supply-chain resilience is its ability to adapt and recuperate swiftly from any disruptions in order to re-establish its normal condition or develop into a new, more desired position. Several studies have suggested strategies for decreasing COVID-19 effects, planning, preparing for future unexpected catastrophic events, supply chain resilience and recovery, and its effectiveness is determined by its ability to act proactively (Chowdhury *et al.*, 2021).

Therefore, the existing lean supply-chain strategy for healthcare is ineffective and vulnerable and may jeopardise economic, healthcare, and national security. The focus of the lean approach is on cost reduction by eliminating non-value-added (NVA) activities, being sustainable, and optimising supplies (Bhaskar *et al.*,2020; Sharma *et al.*, 2020).

Several studies and models have suggested that scaling up production early and making quick choices can help reduce deficits of life saving medicines by using cost-benefit analysis (Lozano-Diez *et al.*, 2020; Mehrotra *et al.*, 2020), without being driven by economic motives (Cohen and van der Meulen Rodgers, 2020). Most crucially, time efficiency is a component in a pandemic-resilient PSC, as it pertains to minimising the "end-to-end" time required for manufacturing and distributing products and services. According to deSousa Jabbour *et al.* (2020) suggestions, value-stream mapping can assist in identifying activities or processes that can be decreased or removed to enhance material flows; by trace-track procurement, production, and delivery orders through real-time information sharing, development of contingency plans, inventory stock-take, modification of production orders, and up-stream supply chain communication.

Cost related to efficient PSC:

It is reported that the pandemic also has a negative effect on supply-chain financial performance (Ivanov and Das, 2020). Additionally, researchers examine how these losses vary in magnitude or duration in response to other variables, such as restriction limits and their length (Chowdhury *et al.*, 2021). Their studies illustrated that the magnitude of financial losses is mostly determined by the number of nations enacting lockdown, its duration, and the timing of facility closures and re-openings at various

levels of a supply chain rather than their restrictiveness. Kuo *et al.* (2021) study covered contingency methods for dealing with pharmaceutical shortages, as well as evidence-based suggestions for assuring a consistent drug supply, medication quality and security, initiative-taking management, information sharing and prompt communication.

To manage the post-pandemic supply-chain process, researchers have proposed employing digital-twins mobile services, and 3-D printing technology and deploying response tactics for PPE and ventilators during and post-pandemic using advanced transportation to ensure timely delivery (Armani *et al.*, 2020), with an artificial intelligence business model development (Bhaskar *et al.*, 2020). Dasaklis *et al.* (2012) suggested the utilisation of non-affected portions of the world as a source of emergency supplies, ordering protocols, safety stock, lead times, and replenishment policies. Finally, stakeholder coordination and collaboration to boost inventories and minimise monetary loss is essential for an efficient PSC (Chowdhury *et al.*, 2021).

4. FINDINGS AND DISCUSSION

A substantial demand and supply disparity was experienced during the COVID-19 pandemic; most notably, the shortage of pharmaceutical products such as disinfectants, sanitizers, ventilations, vaccines, PPE, and healthcare infrastructures (Cundell *et al.*, 2020), which contributed to this situation, making it difficult to combat the pandemic driven SCD. In terms of PSC disruption, the literature analysed the critical factors responsible for this situation. The main factors were shortage of supply, demand fluctuation, logistic shutdown, border closures, lockdown, and travel restrictions. Manufacturers experienced unavailability of imported raw materials, rising prices, and employee absenteeism contributing to production delays (He *et al.*, 2022).

Drug shortage is a critical effect of PSC disruption in most developed and developing countries. According to the Food and Drug Administration-US, hydroxychloroquine (HQC), azithromycin, chloroquine (QC), fentanyl and dexmedetomidine were frequently stocked out (Ayati *et al.*, 2020). A report presented the comparison of drug shortages between the US and Australia which claimed that between 2019 and 2020 the number of drug shortages rose by 37% in the US and 300% in Australia (Cameron and Bushell, 2021). Similarly, Tuesuwan *et al.* (2022) addressed the oral drug shortage in Thailand and its neighbouring countries during the pandemic. The Figure 3 summarises the factors

affecting PSC disruptions and the effects of such disruption identified in this study.
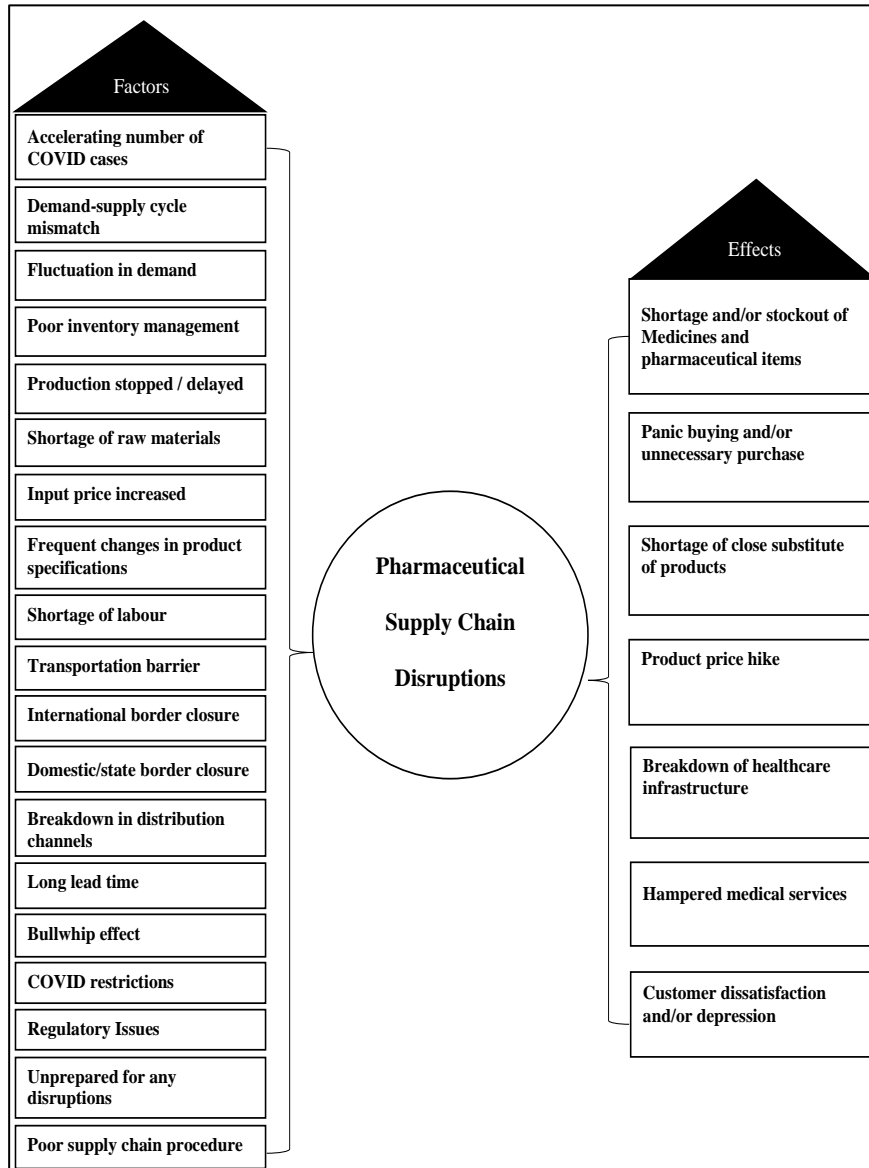

Figure 3. Causes (Factors) and Effects of PSC Disruptions: An Analytical Framework. Source: the Authors.

The demand for PPE such as gloves, surgical face masks, air-purifying respirators, ventilators, goggles, face shields, and N95 drastically surged during the pandemic since it was one of the major elements that aid in the prevention of transmission of infection among the patients and health care workers. Many developed countries including Australia, the US, and Europe, faced shortages as supplier countries had stopped exporting PPE (Boehme *et al.*, 2021). For example, Iran banned PPE export on 1st March 2020 to fulfill their own demands (Bhattacharya *et al.*, 2020).

Various papers have depicted the SCD of PPE in Australia and have suggested improved manufacturing processes to overcome the situation maintenance of standards and solutions (Boehme *et al.*, 2021; Hirunwat *et al.*, 2021; Sandle, 2020). India, an unfortunate victim of high COVID-19 casualty, also suffered from a PPE shortage due to the challenges of bulk PPE production (Bhattacharya *et al.*, 2020). Additionally, hand sanitizer and disinfectants, necessary to curtail COVID-19 transmission, experienced stockouts. Although the ideal sanitizer contains >60% ethyl-alcohol or >70% isopropyl-alcohol, people started using various sanitizers that did not meet the standards (Selam, 2020). Numerous papers have been published concerning sanitizer standards, transmission and solutions (Dicken *et al.*, 2020).

Ventilators and test kits are the most vital medical devices used to save patients in critical conditions. The number of death cases heightened in many developed countries due to the scarcity of ventilators (Iyengar *et al.*, 2020). Furthermore, insufficient healthcare infrastructure is another trigger for PSC disruption that followed nationwide lockdowns and transportation impediments of products. Sriyanto *et al.* (2021) conducted a case study on the sub-Saharan African (SSA) countries, concluding that the shortage of healthcare expenditures depended on the acceleration of confirmed COVID-19 cases.

Ayati *et al.* (2020) identified various short- and long-term impacts of COVID-19 on the PSC in Iran and concluded that repeated changes in demand, rapid research, and product development, and the need for telecommunication and telemedicine. Researchers conducted numerous international case studies to analyse the main factors causing PSC disruption and its consequences. The unavailability and/or shortage of pharmaceutical products was marked as a key reason for PSC collapse, along with production delay, import shutdown, employee abstention, information gap between the supplier and the manufacturer, demand fluctuation, and supply-demand disparity, as shown in Figure 4, which illustrates the 47 papers reviewed to identify the relevant factors.
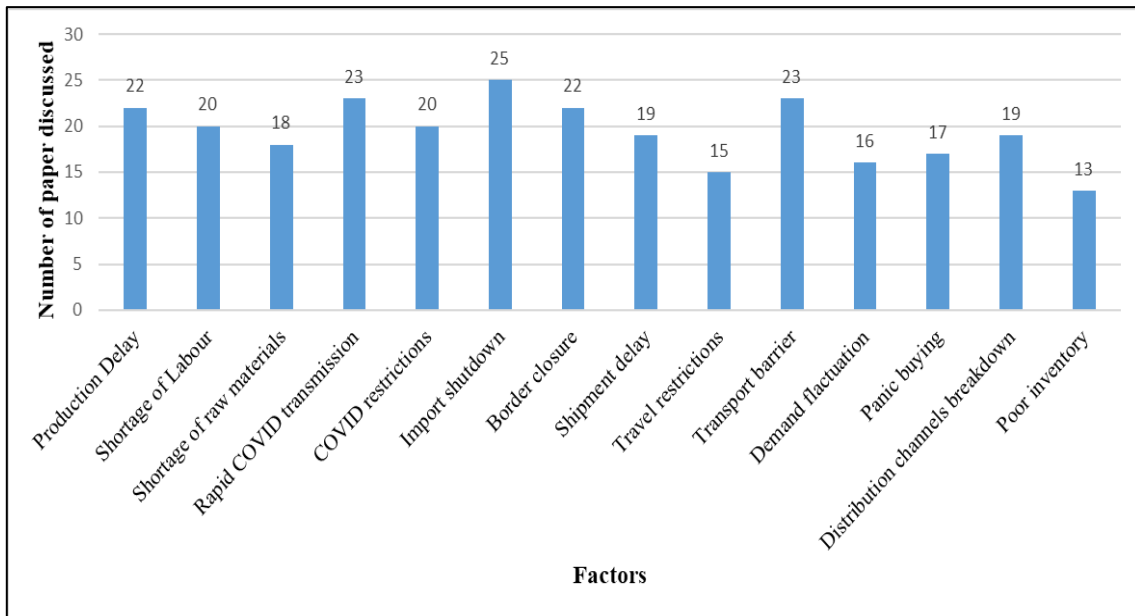
Figure 4. The Number of Papers Discussing Different Factors Affecting PSC Disruptions. Source: Ayati *et al.* (2020); Bhattacharya *et al.* (2020); Boehme *et al.* (2021); Cameron and Bushell (2021); Cohen and van der Meulen Rodgers (2020); Cundell *et al.* (2020); He *et al.* (2022); Hirunwat et al. (2021); Jamshidiantehrani *et al.* (2020); Sandle (2020); Selam (2020); Tirivangani *et al.* (2021) and Tuesuwan *et al.* (2022).

5. LIMITATIONS AND FUTURE RESEARCH

This study has developed a cause-and-effect relationship framework of PSC disruption through a scoping review. However, no in-depth research has been conducted yet to test this framework. This framework can be used for future in-depth study, and research avenues for academics as well as for policymakers and supply chain managers.

6. CONCLUSIONS

This scoping review has developed the causes and effects relationship framework of PSC disruption. Healthcare infrastructure proved to be inadequately designed to tackle a nationwide health catastrophe. Critical reasons noted behind the failure of the PSC, are raw material shortage, logistics, transport, and manufacturers not being able to keep up with the rate of quantity demanded during the pandemic and changing consumer

behaviour. This initial study can provide some directions for the researchers, policymakers, and supply chain managers to understand the causes and effects of PSC disruption and how they study and deal with future disruptions.

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