

## Chapter

# Global Impact of COVID-19 Pandemic on Public Health Supply Chains

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## Abstract

Health commodity supply chains are vital to a well-functioning health system and advancing national and regional health security goals. This study describes impacts of the COVID-19 pandemic on these chains, learnings from it and the challenges faced by countries. It also provides futuristic strategic recommendations for the building of the supply chain to manage the impacts and guide pandemic responsiveness. We used the PRISMA guideline for systematic review to collate relevant information from both published and unpublished literature. Out of 622 screened records, 38 were included in the review. Major impacts were innovation, collaboration, increased technology, research and development, increased prices and shortage of health products, depletion of supply chain personnel. Challenges were lack of visibility, coordination, resilience and strategy for pandemics, potential substandard medicines epidemic, travel restrictions and inadequate scientific knowledge. The studies recommended increased local production and resilience of supply chains. The pandemic disrupted national and international supply chain systems of medical devices, essential medicines and pharmaceutical products due to border closures, transportation and international trade restrictions. It however exposed hidden potentials in Sub-Saharan Africa. There is need to develop supply chain strategy for emergencies, increase local production and talent pool for supply chain management particularly in Africa.

**Keywords:** COVID-19, impact, health supply chain, pandemic

## 1. Introduction

The COVID-19 pandemic has escalated into the largest health crisis of the 21st Century. According to the COVID-19 situation dashboard of the World Health Organization (WHO), the virus has infected more than 117,132,788 people worldwide to date, and has also killed over 2,600,839 [1]. Epidemiological projections show that the outbreak overwhelmed even well-developed healthcare systems [2]. Many countries have thus imposed pandemic suppression measures such as lockdowns and community quarantines in an effort to stem the progress of the pandemic [3].

Health commodity supply chains are a critical element of a well-functioning health system and a vital input to advancing national and regional health security goals. Strong medicine and health commodity supply chains improve health outcomes and build trust in health systems. Robust supply chains provide critical

vaccines, medicines, diagnostics, and other essential health supplies to support communicable disease prevention, control, and response activities [4]. A public health supply chain is a network of interconnected organizations or actors that ensures the availability of health commodities to people who need them. Essentially there are four parts to a supply chain; product manufacturers or the suppliers, distributors, service providers (hospitals, pharmacies, retail medicine sellers) and finally the customers or patients [5].

The coronavirus pandemic is having a clear impact on the supply chains of virtually all manufacturers, retailers, and wholesalers. As the world attempts to navigate through this difficult time, most companies are struggling to maintain a steady flow of required goods and services. Whether it is frozen foods and grocery items, or ventilators and masks, medicines or even the services clinic visits etc), the supply chain has been facing multiple obstacles [6]. This disruption is mainly due to COVID 19 pandemic, emanating from China being the second largest economy in the world and the major supplier of inputs for manufacturing companies around the world. Majority of the original equipment manufacturers in China have stopped production [7]. At present, most of the production capacity of these drugs and chemical precursors are in the United States, China and India. Global supply chains have been disrupted due to loss of labor and raw material inputs, creating ripple effects that cross national boundaries [3].

This chapter describes the impacts of the pandemic on public health supply chain, challenges that countries are facing, learnings from the pandemic and provides futuristic strategic recommendations for the building and rebuilding of the supply chains to manage the impact of the pandemic and guide responsiveness towards future pandemics.

## **2. Data collection process**

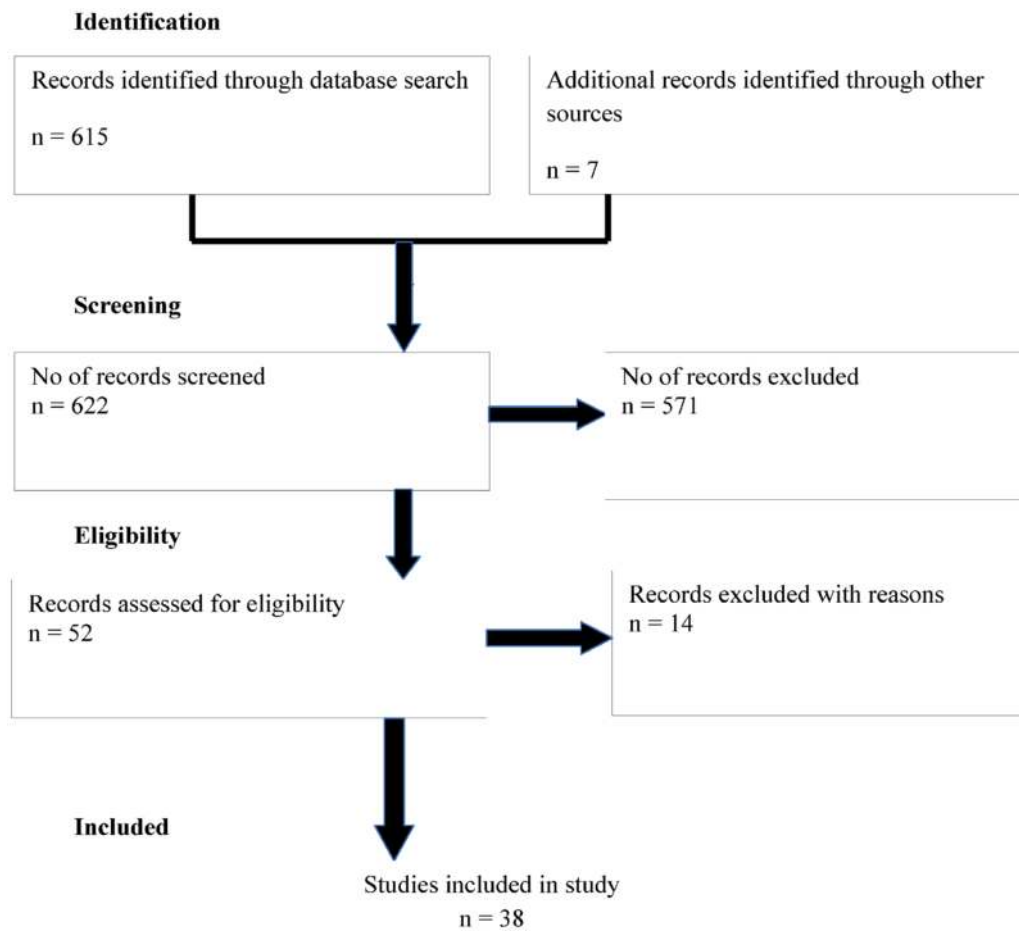
This chapter is an outcome of a systematic review done by using Purdue libraries online access and e-resources centre 'All Databases' search tool. The search was conducted from June to August, 2020 using the PRISMA checklist. We screened 622 records and reviewed 31 peer reviewed publications and 7 unpublished papers from across the countries.

Literature search was done using keywords like "impact of COVID-19", "effects of COVID-19", "supply chain and COVID-19", "health impacts of COVID-19", "global and public health supply chain during pandemics", "public health and supply chain", and "impact of outbreaks" on databases like Pubmed, ProQuest, Google Scholar, Web of Science, Science Direct (Elsevier). We have excluded literatures that did not report challenges, effect or impact of COVID-19 on health supply chain and as well those not reported in English.

**Figure 1** shows the flow chart of this review.

After careful review of the articles, 38 out of 622 screened publications were selected for inclusion in this study. Extracted data were analyzed and sectioned into positive impact, negative impact, challenges, learnings and recommendations.

All the 38 studies included in the review were conducted between February and August, 2020. Majority of the studies reviewed were conducted globally [8], in Africa [9], Asia [2] and United States [5]. A survey published on March 28 by the Chartered Institute of Procurement and Supply found that 86% of supply chains are impacted by the COVID-19 pandemic while another study by the Institute for Supply Management found that between early March and late March, 2020, the number of companies experiencing supply chain impact rose from 80 to 95% [9].



**Figure 1.**  
*Flow of information through the different phases of the review.*

## 2.1 Outcome of systematic review

Our review revealed the following:

### 2.1.1 Positive impacts

While Covid-19 has been blamed for economic downturns, it has shifted organizational focus towards a sustainable supply chain [6]. Other positive impacts include:

1. Creativity and Flexibility among Companies and Countries. Due to the impact of COVID-19, many companies around the world started to re-purpose or re-adjust their production, with many brewing companies and distilleries producing hand-sanitizers, fashion companies producing masks and automotive companies looking to produce ventilators. Some governments and businesses developed a variety of innovative prevention measures such as drive-through testing kits and products that can be utilized all over the world. Countries that have never produced surgical masks, gloves, sanitizers, or ventilators turned to domestic production [7, 10–13].
2. Increased Availability and Utilization of Technology and Innovation in the Health Sector:

- Technology driven health services which was largely considered a novelty or luxury, now has the opportunity to demonstrate real value as traditional healthcare services become overwhelmed by patient load demands [7, 14].
- Some organizations were able to quickly mobilize by leveraging existing tools for source-code dissemination, accelerating innovation and targeted problem-solving. Notably, the COVID-19 emergency has highlighted the power of the Maker community to make a real and immediate impact [13].

### 3. Diversification of suppliers and logistics models:

- The pandemic has thrown up opportunities for entrepreneurs to take advantage of the need for sourcing raw materials along more efficient commodity routes and methods such as railways, increase in dual sourcing of key components and a preference for larger, more financially stable suppliers with multiple manufacturing sites [14, 15].
- Companies that operate regularly in the supply chain should expect to see the emergence of stronger, more conservatively financed, multi-site suppliers as a long-term outcome of the pandemic [14].

### 4. Increased Capacity in Research and Development: As the world manages to contain Covid-19 outbreak, various countries and firms are focusing on finding a vaccine, developing protocol to treat infected patients, adopting capabilities which ensure the integrity of the processes and the quality of the products and creating a safe working environment for employees [6, 7, 13].

#### *2.1.2 Negative impacts*

Unlike other disruption risks, the epidemic outbreaks start small but scale fast and disperse over many geographic regions causing simultaneous disruptions in supply, demand, and logistics infrastructure [16]. A report published on 21 February 2020, indicated that 94% of the companies listed in the Fortune 1000 list were already facing SC disruptions due to the COVID-19 [17]. Other negative impacts include:

1. Shortage in essential and non-essential medicines, raw materials, medical and pharmaceuticals products: As a result of the surge in the pandemic which led to the inevitable lock down of the economy across affected countries, there has been a noticeable decrease in production and exportation of equipment, raw materials, as well as finished products across different countries [6]. Production supply shortages, transport interruption and the virus containment measures taken by the government was limiting market access, hampering manufacturing activities and nudging the economy towards an inflationary recession which is adversely affecting the manufacturing sector, including that of health products production [7, 16, 18–20]. It has certainly surprised many to discover just how much western countries (in which shortages are particularly prevalent) rely upon global supply chains to obtain medical supplies from China and low-cost economies [21]. However, these networks have poor resilience to global disruptions, with nearly 35% of manufacturers reporting disturbances due to the global Corona virus pandemic [8, 11, 22]. Given the expected increase in COVID-19 cases and global competition for sourcing PPE, many medical facilities currently do not have enough stock and/or reliable resources to meet the anticipated demand [10].

2. Congestion of cargo terminals and delays in transportation of food and health commodities due to travel ban and movement restrictions: The severe spread of the virus into Europe and the United States has blocked the movement of the products and materials worldwide [8]. Many manufacturers and service providers experienced disruptions as more than \$100 million worth of goods were stuck in China during the China lockdown [7]. For many countries and firms, the inability to respond to the Covid-19 outbreak lies in its transportation services [23]. The world's largest 1,000 companies had over 12,000 factories, warehouses and operations in quarantined regions in early March, 2020 [19]. If cargo does not flow, within days, there will be no space in the terminals to discharge other cargo and some of the cargo waiting to be discharged includes food and medicine [7].
3. Depletion of human resource for supply chain: COVID-19 has cost hundreds of thousands of human lives globally including healthcare professionals, and exposed the weaknesses of national health systems worldwide [12]. Global supply chains have been disrupted due to loss of labor and raw material inputs, creating ripple effects that cross national boundaries [3].
4. Some big multi- nationals have left themselves dangerously exposed to supply-chain risk owing to strategies designed to bring down their costs [24].
5. Reduced access to medicines due to increase in prices of medicines and movement restrictions: In Nigeria, the lockdown which was accompanied with the closure of borders and travel ban across states led to a significant drop in the quantity of essential medicines in the health facilities with a consequent increase in the prices of medicines, hand sanitizers, face masks, personal protective equipment, and other medical equipment used for providing health care, making it difficult for consumers to get the medicines they need [25].
6. Reduced patronage to small scale suppliers: An increase in dual sourcing of key components and a preference for larger, more financially stable suppliers with multiple manufacturing sites presents new challenges for smaller and more leveraged companies, regardless of their expertise [14, 15].

### *2.1.3 Challenges*

The COVID-19 pandemic has triggered a number of challenges that have led to shortages and price hikes, and could potentially fuel an epidemic of fake and substandard medicines [26]. Findings from the reviewed literature reported the following challenges:

1. There is lack of visibility, collaboration and coordination of real demand and supply [7]. A survey with over 700 respondents conducted by Bass ware found that 60% of responding procurement managers experience a lack of transparency in their supply chain [9]. Absence of supply chain strategy for pandemics: Decision-making is executed under epistemic and stochastic uncertainty [27, 28].
2. Some supply chain disruption are not included in regular supplier performance metrics and such, unplanned for. Most supply chains are still based on reactive or transactional model, therefore, it could take several days or month to adjust supply chains during pandemics [7]. It has become extremely challenging to continue the operations of supply chains as the operations of some



parts of the supply chain in some firms has stopped with little or no alternatives during disruption [7, 29]. ISM also found that 44% of respondents to its survey did not have plans in place to cope with supply disruptions from China [9].

3. It is a great challenge to provide medical supplies (such as masks and protective clothing etc.) and equipment (for checking, testing, and monitoring the disease etc.) to meet the needs of treatment, protection, and control [7]. In a pandemic situation, the demand of the essential products increases expressively; on the other hand, the supply of the raw materials decreases considerably with a constraint of production capacity. These dual disruptions impact the production process suddenly, and the process can collapse without immediate and necessary actions [8, 16, 30]. Limitation on international trade and travel; The ban on the international travel during this pandemic may pose a serious challenge to the healthcare system in Nigeria and across Africa because of heavy reliance of Nigeria and other developing countries on importation of medicines, API and other needed resources for drug manufacturing from other countries [31]. Due to severe disruptions (e.g., manufacturers closed or partially closed, air-ports operating with harsh restrictions, shortages of medical equipment and supplies) recorded, a good number of industries including health commodity manufacturers may experience ripple effects [17, 29].
4. Cost and legal issues: Another challenging part is keeping cost under control which includes higher production costs, shipping costs and agreed costs of pending orders. A legal issue related to disagreeing the agreed cost as a Force Majeure clause or not, poses legal challenge for every company [32].
5. Wrong supply chain success function shift, which focuses on just cost savings and not revenue-assurance or sustainability [7]. A lot of the resilience challenges have arisen from a cost obsession and short-term cost focus in supply chain management [9].
6. Once effective pharmaceutical treatments are found, there will be the major engineering challenge of ramping up production at a rate that matches the pandemic [27]. Planning will be hindered by the lack of solid scientific knowledge about COVID-19 and inadequate literature on pharmaceutical supply chain (PSC) network design in the disastrous situations and other uncertainties (current literature on disruption recovery strategies and modeling during pandemics is mostly limited to humanitarian logistics) which make demand projections highly uncertain [16, 22, 27].
7. Limited supply chain talents in Africa [28].

#### *2.1.4 Learnings*

1. Social Resilience among Supply Chain Partners, Healthcare professionals and Patients: Most supply chains are transactional in nature but transactional supply chain will not be beneficial during and post Covid-19 [6] Thus;
  - It is critical to prepare health care professionals to build resilience in their interactions with patients and other stakeholders [12]

- By developing a culture of collaboration across its supply network, a firm can develop trust among supply chain partners that can help in data-sharing and joint problem-solving [6]
  - Covid-19 has forced companies to lay greater emphasis on the environmental and social aspects of public health supply chain and not just the economical aspect [6, 33]
2. Inflexibility of Supply Chains: Most firms follow strict rules for their supply chain such as; specific number of days for distribution, specific production time, delivery rules, etc. These responses have proved to be inadequate during the crisis. Thus, reacting to the Covid-19 requires flexibility in the supply chain and the overall ecosystem of a firm;
- The central learning from Covid-19 is to diversify production, sourcing, and logistics whenever and however required such that external shocks cannot disrupt the supply chain [6].
  - We also found evidence that centralized procurement and tendering can achieve direct cost savings, while supply chain management program can reduce drug stock outs and increase drug availability for populations [34].
3. The Decoupling from China's Supply Chains: COVID-19 has accelerated two powerful trends for the future, the decoupling from China's supply chains and the relocation of strategic manufacturing operations out of China [12]. A study by corporate data analytics firm, Dun & Bradstreet, reported that 51,000 companies around the world have one or more direct suppliers in Wuhan and at least 5 million companies around the world have one or more tier-two suppliers in the Wuhan region, where COVID-19 originated [18]. In US, there's been bipartisan support for legislation that would study the current medical equipment supply chain and develop an action plan to potentially address the country's dependence on foreign-made products [21].
4. Strategies to deal with Major Outbreaks
- Designing an appropriate pharmaceutical supply chain network for pre-positioning and distributing drugs at post-disaster plays an important role in decreasing the response time and the number of casualties.
  - Pre-positioning of emergency supplies belongs to the preparedness phase of a disaster that brings about some advantages for the Humanitarian organizations [22].
5. Analysis of the Italian production network has found that sectors are both highly connected and asymmetrically connected. Hence, a local shock due to lockdown policy propagates through the whole economy and generates a sizeable global disturbance. This confirms the importance of value chain analysis in investigating how the economy adjusts to dislocation and destruction of parts of its productive capacity [35].
6. The current impact of the COVID-19 outbreak on the manufacturing firms is already very severe and medium-to-long-term impacts are predicted to be

higher than that of any other previous major outbreaks such as 2003 SARS and 2009 H1N1 [21, 36–38].

### *2.1.5 Recommendations*

Key levers for de-risking the supply chain include the need to balance global sourcing with near shore and local sourcing, the adoption of multiple sources and a greater utilization of information technology to drive more complete and immediate information availability. Talent management in supply chain management needs to promote a focus not just on costs, but also on resilience as well as on learning from current events to improve decision-making [10, 30]. Findings from the reviewed literature reported the following recommendations:

1. **Strengthen Local Manufacturing Capacity and Fortify local supply chain:** The global scientific community has been galvanized into action in a frantic search for a cure for COVID-19. Greater collaboration between governments and industries will be needed to ensure minimum disruption in global supply chains. Firms also need to collaborate with multiple stakeholders and be more strategic in their approach to supply chain management. Companies have to come up with alternative means of raw materials sourcing and identify other modes of cost benefit transportation. This will also involve identifying urgent research and development challenges for pharmaceutical supply chains. There should be increased R & D by local universities who should create specialized post-graduate schools that focus on research, while also recruiting and training fresh lecturers who focus on research and product/process development to grow the domestic manufacturing sector [6, 12, 15, 16, 22, 28, 29, 32, 39].
2. **Technological Augmentation and Utilization:** Studies have recommended new supply chain technologies that dramatically improve collaboration, visibility, agility and optimization across the end-to-end supply chain, understand complexities and support companies' ability to resist such shocks from impact of any pandemics or rare events. Block chain systems can assist in keeping the data needed for recoveries such as information and data for production capacity, human resources requirements, information of supplier capacities, and emergency suppliers [6, 17, 30, 32, 38, 40].
3. **Policymakers and program managers should examine the root causes of inefficiencies in pharmaceutical supply chain and procurement processes in order to determine how best to improve health systems performance in their specific contexts.** In addition they should consider the root causes of programmatic challenges to purchasing and distributing health products in their context and identify specific interventions that can strengthen these processes. As the evolution and implications of the COVID-19 crisis are still unfolding, we posit that exploring the experiences and strategic responses of Asian countries may shed some useful light on ways to combat COVID-19 for the policymakers and supply chain managers in the rest of the world [12, 34].
4. **Development and Assessment of supply chain strategies:** Optimal supply chain planning taking into account agility, resilience and sustainability are important. The negative impact of the pandemic has fostered the need for development and implementation of health supply chain strategy. The next-generation supply chain needs a significant change in outlook. Based on our analysis,



we recommend firms adopt a forward looking approach. These forward-looking strategies must comprise of multiple facets of the supply chain including people, processes, and technology.

Devoting resources for supply network mapping as a risk-mitigation strategy. A firm can design its supply network in such a way that it can balance risk and operational flexibility, manage supply chain disruptions, and keep supply chain agile. Brian Higgins, a principal Supply Chain & Operations Leader of KPMG, US has recommended some very pertinent action points for the long term:

- Build agility and speed into your supply chain by creating Micro-Supply Chains;
- Assess opportunities to diversify the supplier base and identify geographically diverse suppliers to onboard in the event of emergency. Consideration should be given to dual-sourcing for critical components.
- Move towards a Supplier-Centric approach to procurement, further integrating your supply chain with those of your direct suppliers to Original Equipment Manufacturers and direct suppliers to Tier-1 and Tier 2 suppliers
- Look to develop more collaborative relationships with critical suppliers in other to build organizational resilience as it is highly unrealistic to completely exit the Chinese market because of the supplier ecosystem in the place, however, organizations should understand their supply chain more deeply.

A study proposed a framework for operations and supply chain management at the times of COVID-19 pandemic spanning six perspectives, i.e., adaptation, digitalization, preparedness, recovery, ripple effect, and sustainability. Assessment of COVID-19-related procurement and supply chain risks and life-cycle sustainability assessment of pharmaceutical product systems and development of drug allocation strategies under resource or supply constraints were recommended [6, 17, 41].

5. Human resource supply chain strategy that includes the selection of the critical workforce that can handle the turbulence in any environment. The supply chain initiatives will require a focused Crisis Management head whose skills and responsibility will be to communicate to all stake holders, consolidating requirements and setting priorities and work on risk mitigating methods of supply chain during non-crisis period. This will need scenario planning, resource optimization, and efficiency management. There is a greater need for a firm to look beyond profitability. Ensuring the well-being of not only a firm's employees but also those employed even with suppliers is critical if a firm wants to avoid disruptions in the supply chain [6, 32].
6. Utilize suitable resilience strategies for designing pharmaceutical relief networks, employ other types of supply contracts, consider the coordination and collaboration of multiple humanitarian organizations in a collaborative setting and address the case in which successive disasters may happen. Relief managers can ensure the high availability level of pre-positioned pharmaceutical items by paying attention to their procurement time and shelf-lives. By utilizing mobile pharmacies the distance between relief shelters and drug supply sites can be reduced, and the distribution of drugs to inaccessible areas can be

possible. Infectious disease outbreak preparedness strategies should incorporate primary healthcare services and other health system modalities to cater for non-pandemic-related conditions [18, 22].

Suppliers should manage the perception of their readiness to adapt to changing situations. Those that demonstrate competence will be rewarded as their customers look back in the coming years. Rather than ignore or complain about uncertainty, suppliers will be well-served if they can demonstrate plans that show customers they can reliably manufacture regardless of societal disruptions. Suppliers also need to be dynamic by focusing on multiple best practices explored by other suppliers, competitors and ecosystem in order to optimize cost and delivery, improve visibility across the network, and accelerate reaction times to issues in production and delivery [6, 14, 15].

## **2.2 Discussion and conclusions**

The COVID-19 pandemic has impacted global health product supply chains, affecting key materials and ingredients, finished health products, logistics, and shipping medical devices, essential medicines and pharmaceutical products as a result of border closures, international trade restrictions and transportation problems [42]. The COVID-19 pandemic clearly shows the lack of resilience in supply chains and the impact that disruptions may have on a global network scale as individual supply chain connections and nodes fail [41].

As did HIV, the COVID-19 is likely to have profound and long-term consequences on global health care supply chains. The HIV pandemic transformed health care supply chains globally and in particular in lower and middle-income countries, (LMICs) leading to the mobilization of new financial resources for health care products, service delivery, and the creation of international bodies (including The Global Fund and PEPFAR) [43].

The short-term effects of COVID-19 on global health care supply chains have been severe; factory and border closures, transportation disruption, shifting demand, and price increases but it is more important to reflect on what the long-term consequences will be and how global changes will affect the LMICs. This is because LMICs are in their early stages of pharmaceutical development; thus they rely on importation of drugs, raw materials and equipment from countries outside the region, notably India and China.<sup>18</sup> Researchers wonder whether the changes will be positive overall or if countries will revert to the same systems that left us unprepared for an international pandemic. This review was unable to find answer to these questions. However, crises like pandemics tend to have lasting impacts, and it is likely that the short-term disruption of health care supply chains we are seeing will result in longer-term structural changes. This highlights the need for policymakers to address challenges to large-scale and sustainable drug manufacturing, using the COVID-19 situation as a learning opportunity. It is interesting that some companies are offering strong technological solutions, which may help them survive and even prosper. While the hope is that COVID-19 will increase recognition of the importance of strong health care supply chains with commensurate investment, there will also be pressure on funders to rebuild their own shattered economies. There will be pressure to turn inward, certainly over the short term. There may also be opportunities for alternative financing mechanisms including venture capital [43]. The review has noted the fact that disruption does not necessarily mean negative outcomes and that it is incumbent on all health supply chains organizations to turn this disruptive event into positive change.

The COVID-19 pandemic is a disruption of an unprecedented magnitude, which is testing the resilience of global supply chains. The ability for a supply chain's operators

to effectively plan, enabling a means for the supply chain to absorb, recover from, and adapt to disruptions of various lengths, impacts, and probabilities, is essential to ensuring the supply chain's function and success. For a supply chain, resilience measures the ability to prepare for and provide essential functions during a disruption, and then to recover from and adapt post-disruption into a form that is better suited to the new "present." Although sustainability, robustness, risk mitigation, leanness, and other supply chain management practices are important for business success, supply chain resilience is unique in its focus on recovery following a disruptive event [44].

Maintaining the supply chain of pharmaceutical products is not only paramount to cover the immediate medical response but will be fundamental to reducing disruption of the healthcare delivery system, which requires constant medicines, diagnostic tools and vaccines for smooth functioning.

In Nigeria, for example, over 70% of the prescribed medications are produced from active pharmaceutical ingredients (API) primarily sourced from firms in China and India. Uninterrupted access to medicine is an integral part of healthcare systems much needed and essential for the well-being of the population, but the COVID-19 pandemic has threatened this [31].

There is need to consider the new digital technologies that have potential to improve the ripple effect control in cases of epidemic outbreaks. Making innovations and data work for the supply chain resilience in crisis times, understanding and progressing the research of how these technologies can be used boost supply chains resilience, are important future research areas with a particular focus on data analytics, artificial intelligence, and machine learning [45].

There is minimal risk of bias in this study as articles were merely reviewed as presented and reviewers were not privy to the original data of the individual studies. Reviewers were also not interested in the outcome of the review but aimed at providing recommendations to country supply chains for the benefit of public health. None of the reviewers is a publisher of any of the articles reviewed. The review is limited to the competences of the reviewers in interpreting the results and to the fact that the coverage of included articles was flexible and neither restricted the review to articles conducted in homogenous settings nor compared their findings.

This study buttresses the need to devise and institute clear strategies on supply chain management in country and regional emergency responses, promotion of local manufacturing of medicines and other health products to reduce the extensive dependency on importation from international markets and increase the talent pool of supply chain management especially in Africa.

The review concluded that many manufacturers and service providers in some countries are already experiencing severe shortage of essential and non-essential raw materials including medical and pharmaceutical products, in addition to intermediate inputs, due to the COVID-19 pandemic and its consequent border closures, trade restrictions among nations, and transportation problems. The COVID-19 pandemic however exposed some hidden potentials in many countries especially in Sub Saharan African. There is need for health supply chain resilience through development of a reliable supply chain strategy for pandemics and other such emergencies.

## **Conflict of interest**

The authors declare no conflict of interest.

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