

Unveiling Shortages in the Humanitarian Supply Chain: Root Causes of PPE Shortages during the COVID-19 Pandemic

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Abstract. The COVID-19 pandemic triggered a surge in demand for personal protective equipment (PPE) worldwide, such as masks, gloves, and hand sanitizer gel, leading to significant disruptions in the supply chain. This research investigates the root causes of these disruptions, aiming to provide insights into the challenges faced during the pandemic. Through a comprehensive literature review and employing Root Cause Analysis methodology, this study unveils the multifaceted factors contributing to the disruption of the PPE supply chain. The analysis reveals the interconnected nature of these issues, emphasizing the need for strategic supply chain management. The findings underscore the importance of diversified supplier networks, the establishment of safety stocks, and enhanced crisis response strategies to ensure the continuous availability of PPE. Additionally, the study highlights the significance of public education and responsible purchasing behaviors to mitigate disaster-related buying behaviors defined by Holguín-Veras et al. (2023) and promote equitable access to essential equipment. Insights derived from this research offer critical implications for crisis response strategies, emphasizing preparedness, collaboration, and supplier network resilience. Future research directions encompass exploring distribution efficiency, technological innovations in inventory management, supply chain resilience, economic impacts, sustainability, consumer behavior, international cooperation, and public education strategies, all aiming to fortify supply chain management and enhance PPE availability during emergencies.

Keywords: PPE shortages, Supply chain disruptions, COVID-19, Root cause analysis, Healthcare supply chain.

1. Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has brought with it a range of challenges in terms of both public health and social issues across the globe. One of the widely recommended mitigation measures to contain the spread of the virus was the adoption of face masks and hand sanitizer gel. The World Health Organization

(WHO) and the Centers for Disease Control and Prevention (CDC) were quick to recommend the use of face masks as an effective measure in reducing transmission of the virus since the start of the pandemic.

In this context, the WHO issued comprehensive guidelines regarding the use of masks and hand sanitizer gel, highlighting their effectiveness in preventing the spread of the virus. At the same time, the United Nations (UN) launched a Global Humanitarian Response Plan for COVID-19, highlighting the urgency of coordinated actions on an international scale.

With the massive advent of the pandemic, hospitals began to run out of some essential products, due to their high consumption, such as surgical masks, N95, aprons and hats. Industries were not prepared to produce on a very high scale, and this was compounded by absenteeism due to the COVID-19 contagion. Several smaller companies began production to supply the market, but with low quality and therefore low safety. Most of the products were imported from China, which, due to COVID-19, stopped exporting. During the year, several companies and industries began to reduce production due to the lack of raw materials available on the market. These deficits caused inflation, and some products experienced an increase of up to 1,000% in their unit value.

According to Dave et al. (2022) throughout the pandemic, managing PPE was an immense challenge. Several surveys have shown that less than 40% of healthcare professionals have used all required PPE during a patient visit.

Research in this area is justified by the need to understand the variability in the acquisition of products such as masks, alcohol, and gloves during the COVID-19 pandemic. It considers their impacts on public health, underlying behavioral and cultural factors; economic implications of shortages and increases in price of essential products; issues of quality and safety of supplies, in addition to the importance of transparency in the acquisition of these products.

Therefore, the question we seek to answer is:

- What are the main causes of disruption in the PPE supply chain?

Therefore, this research aims to carry out a diagnosis of the humanitarian supply chain during the first year of the COVID-19 pandemic, identifying the root causes of disruption in the PPE supply chain.

This research paper delves into the critical examination of the humanitarian supply chain during the initial phase of the COVID-19 pandemic, specifically focusing on the root causes behind the disruptions in the PPE supply chain. However, it's

important to acknowledge certain limitations inherent to this study. Firstly, the scope of this research primarily revolves around the healthcare sector, particularly hospitals, and healthcare professionals. While this sector undeniably plays a pivotal role in the pandemic response, other essential industries and segments of society might experience distinct challenges and implications related to PPE shortages. For instance, frontline workers in non-healthcare sectors, essential service providers, and even the public faced difficulties accessing adequate PPE during the pandemic.

Additionally, this study employs Root Cause Analysis methodology to dissect the multifaceted factors contributing to the disruptions in the PPE supply chain. While Root Cause Analysis is a robust analytical tool commonly used in problem-solving methodologies, its application might encounter certain limitations. The effectiveness of Root Cause Analysis heavily relies on the availability and accuracy of data, which could be challenging to obtain, especially during rapidly evolving crises like the COVID-19 pandemic. Moreover, the complexity of supply chain dynamics and interdependencies among various stakeholders may pose challenges in accurately identifying and prioritizing root causes. Despite these limitations, Root Cause Analysis serves as a structured approach to unraveling the underlying issues and guiding strategic interventions in supply chain management.

Despite these limitations, this research endeavors to offer significant contributions to the understanding and mitigation of PPE shortages during emergencies like the COVID-19 pandemic. By unraveling the root causes of disruptions in the PPE supply chain, this study aims to provide critical insights for crisis response strategies. The findings emphasize the imperative of strategic supply chain management practices, including the establishment of diversified supplier networks and the maintenance of safety stocks. Furthermore, the study underscores the importance of enhancing crisis response strategies and fostering collaboration among stakeholders to ensure the continuous availability of PPE. Additionally, by highlighting the significance of public education and responsible purchasing behaviors, this research seeks to mitigate disaster-related buying behaviors and promote equitable access to essential equipment.

The article is structured into five sections. After this introduction, section 2 presents the main concepts relating to humanitarian supply chain disruption. Section 3 addresses the research methodology adopted. Section 4 proposes an analysis of the root cause of the data presented. The final section offers the authors' main conclusions and prospects for future research.

2. Methodology

According to Ropero-Padilla et al. (2022), Root Cause Analysis (RCA) methodology is an incident analysis approach consisting of a set of reactive patient safety techniques

that posits that problems are best managed by attempting to rectify or remove root causes rather than simply addressing immediate results.

Cause Mapping is a method for visually explaining why an event occurred by connecting individual cause and effect relationships to reveal the system of causes of a problem, as Aurisicchio et al. (2016) state.

In this research, after completing the data collection phase, the research continued with an analysis using the RCA methodology with the aid of SoLogic software. This step played a fundamental role in the investigation, aiming to identify and understand the root causes or roots of the problem of interest.

SoLogic software was used to apply specific RCA techniques and methods. This analysis aimed to identify the root causes that contributed to the disruption of the PPE supply chain in the context of the health sector. The software provided the ability to visualize data in different formats, enabling a systematic and accurate approach to searching for root causes.

During the analysis, multiple perspectives and variables were considered in order to examine the issue in depth and identify underlying factors that might not be immediately obvious. The findings resulting from this analysis were then used to provide valuable insights and recommendations to address the identified root causes, with the aim of improving the efficiency of the humanitarian supply chain in line with the research objectives.

Thus, the RCA carried out with the SoLogic software represented a crucial step in the research process, enabling a more complete and precise understanding of the problems investigated and, consequently, guiding decision-making and the implementation of appropriate corrective measures.

3. Results and discussion

When dealing with an event such as the disruption of the supply chain during the COVID-19 pandemic, there are numerous elements related to the cause and purchase history. According to the analysis of the data demonstrated previously, the failure tree presented in the RCA diagram represents the main factors that led to the rupture of the hospital PPE supply chain, portraying the main topics, in a summarized and objective way.

To create an RCA diagram, it is necessary to know the event being analyzed. In this case, the event analyzed was the disruption of the hospital PPE supply chain during the pandemic, and knowledge of the factors related to the disaster comes from data collection and reading official reports.

In this research, the RCA diagram was created using the SoLogic software, exclusively for this purpose. The choice of software was made due to the ease of handling and objectivity of the elements available to create an RCA. Figure 1 represents the structure of the diagram, and the stratification of causes is addressed throughout the section.

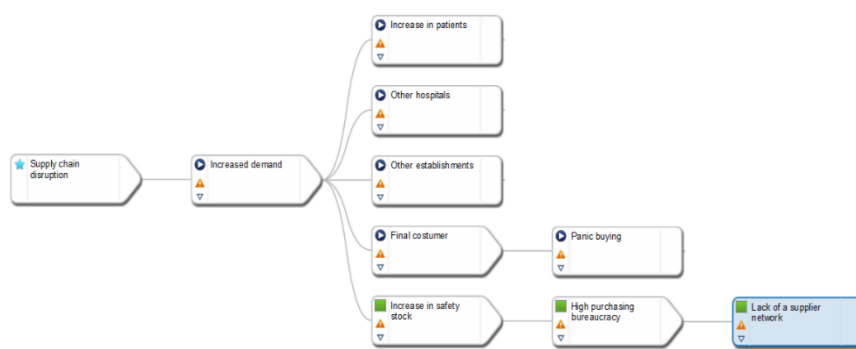


Fig 1. RCA diagram

The RCA diagram is read and interpreted from left to right, starting from a focal point. From then on, the main actions (represented by the triangle inside the blue circle) and conditions (represented by the green square) that contributed to generating the event, which is located on the left of the diagram, are portrayed.

Therefore, Figure 2 represents the main factor that triggered the disruption of the supply chain in question.



Fig 2. Cause of supply chain disruption

The sudden and substantial increase in demand for products such as PPE can trigger a series of supply chain issues. One of the main reasons for this is that the unexpected increase in demand can overwhelm the entire chain, from production to distribution. Companies may have difficulty increasing production in line with demand, resulting in

delays in delivery and shortages of products on the market. Furthermore, the lack of raw materials and components needed to manufacture products can become an obstacle, especially if suppliers are unable to keep up with growing demand.

Logistics may also be affected, with congestion at ports, lack of transport capacity and delays in customs operations contributing to significant delivery delays. Businesses may often not have enough inventory to handle unexpectedly high demand, resulting in empty shelves and frustrated consumers. Moreover, increased demand can lead to fierce competition for resources such as raw materials and production capacity, which can increase production costs.

In global crisis situations, such as the COVID-19 pandemic, where demand for PPE has increased around the world, there is global competition for the same products, making the situation even more complex. Disruptions in one part of the supply chain can have a ripple effect, affecting other parts of the production and distribution process. Finally, a lack of supply chain resilience, including the absence of contingency plans and flexibility, can make companies particularly vulnerable to disruptions caused by unexpected increases in demand. Figure 3 illustrates the main factors that triggered the increase in demand in question.

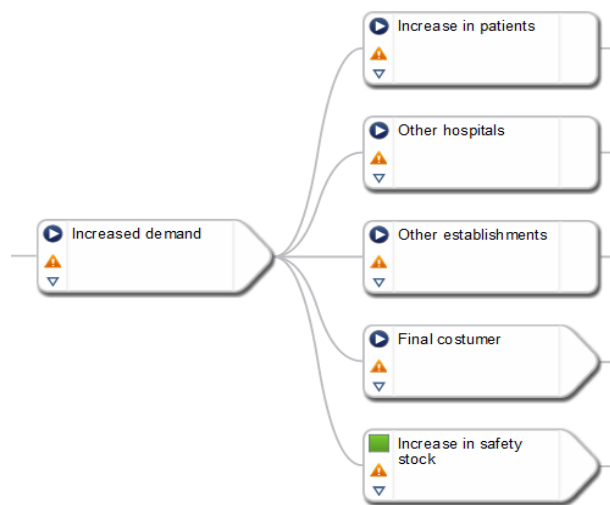


Fig 3. Cause of increased demand

The increase in demand for PPE is intrinsically linked to several factors, with the increase in the number of patients in hospitals being one of the main drivers of this phenomenon. In situations of contagious disease outbreaks, such as the COVID-19 pandemic, the demand for PPE, such as masks, gloves, and gowns, increases exponentially due to the greater number of patients requiring medical care and the need to protect healthcare professionals.

Furthermore, purchasing by end consumers plays an important role in increasing demand for PPE. Consumers in general, concerned about their own safety, are seeking to purchase masks and other PPE, which further increases the pressure on the supply of these products, which were initially intended mainly for healthcare professionals.

The need to increase safety stocks is also a significant factor. Healthcare institutions recognize the importance of maintaining strategic reserves of PPE to be prepared for sudden spikes in demand, such as those seen in public health emergencies. This leads to advance purchasing and stockpiling of larger quantities of PPE, contributing to increased demand at critical times.

Additionally, other establishments, such as medical clinics, nursing homes, health centers and companies, are also beginning to purchase PPE to protect patients, employees and customers, further increasing the demand for this equipment.

In Figure 4, the root cause of the increase in purchasing demand by end consumers can be seen.



Fig 4. Cause of final consumer purchase

The purchase of PPE by end consumers during crises, known as panic buying or disaster-related buying behaviors, is a common reaction to situations that pose a threat to public health, such as outbreaks of contagious diseases. This behavior is driven by fear, uncertainty, and the sense of urgency that many individuals experience in the face of a health threat. In particular, the COVID-19 pandemic served as a striking example of this phenomenon, with consumers rushing to purchase face masks, gloves, and other PPE in large quantities.

Panic buying, or disaster-related buying behaviors, according to Holguín-Veras et al. (2023) often follows a pattern of herd behavior, where people observe others buying large quantities of PPE and feel the need to do the same, fearing the products will sell out quickly. The spread of alarming information on social media and traditional media also plays a crucial role in amplifying panic and promoting mass purchase.

One of the underlying reasons for these purchases is the perception of scarcity, even if the actual scarcity of products does not exist. Fears that PPE will run out lead people to stockpile these products, creating artificially high demand. This impulsive purchasing can have negative consequences, such as real shortages of PPE, inflated prices, and a lack of access to this equipment for healthcare professionals and others who truly need it.

It is important to recognize that education plays a key role in mitigating panic buying. Providing clear information and solid guidance from public health authorities can help reduce panic and ensure people use PPE appropriately and responsibly. Furthermore, measures to avoid price gouging and equitable distribution of resources are also crucial to ensuring that PPE is available to those most in need, such as healthcare professionals who are on the front lines fighting the disease. Finally, Figure 5 shows the main reason for the need to increase safety stock.

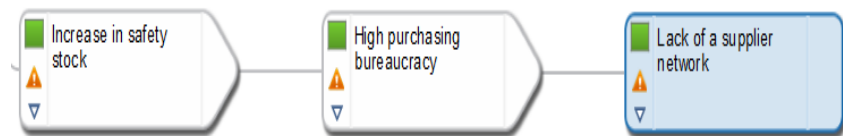


Fig 5. Cause of increase in safety stock

The bureaucracy associated with the acquisition of PPE by hospitals plays a fundamental role in the need to increase the safety stock of this equipment. Hospitals are highly regulated institutions, and PPE purchasing procedures often involve complex bidding processes, compliance requirements, and rigorous quality and safety standards. These bureaucratic processes can be time-consuming, from identifying the need for PPE to successfully completing the acquisition.

One of the main challenges is the slow purchasing deadlines, often associated with public tenders and government acquisitions. During this time, demand for PPE can increase rapidly, especially in situations of disease outbreaks or health crises, which can result in existing stocks being exhausted. Additionally, government regulations and

quality requirements can add additional layers of complexity to the procurement process as PPE must meet healthcare-specific standards.

Hospitals also have their own internal procedures that involve technical assessments and approvals for PPE purchases. While these processes are necessary to ensure that purchased products meet clinical and safety needs, they can contribute to delays in procurement. This can be particularly challenging in urgent situations, when speed in obtaining PPE is crucial.

To address these issues, hospitals often choose to maintain strategic stocks of PPE, known as safety stocks. These extra stocks are maintained as a precaution to ensure that sufficient supplies are available in emergency situations when demand may exceed normal procurement capacity. This helps ensure continuity of healthcare and the protection of healthcare professionals at critical times.

The lack of an accessible supplier network is one of the root causes of problems related to the acquisition of PPE in times of crisis. This lack of affordable suppliers can be attributed to several factors, and this shortage in the supply chain directly impacts the ability of hospitals and healthcare institutions to buy PPE in an effective and timely manner. Here are some reasons why this lack of accessible supplier network is problematic:

- **Reliance on Limited Suppliers:** In many cases, hospitals and healthcare institutions depend on a limited number of suppliers to purchase PPE. If these suppliers face production capacity issues, supply chain disruptions, or stockouts, hospitals are in a vulnerable position and may not be able to meet demand.
- **Global Competition for Resources:** In global health crisis, such as the COVID-19 pandemic, competition for PPE occurs on a global scale. This means that many countries and institutions are seeking the same resources, leading to massive demand that can overwhelm existing production capacity.
- **Dependence on Imports:** In some cases, PPEs are imported from other countries, which adds complexity to the supply chain. Disruptions to imports due to trade constraints, customs blockages, or logistical issues can create delays in the availability of PPE.
- **Unreliable Suppliers:** Lack of a diverse network of accessible suppliers can result in reliance on suppliers that may be unreliable or unable to consistently meet demand. This increases the vulnerability of healthcare institutions.
- **Inflated Prices:** When the supply of PPE is limited due to a lack of affordable suppliers, the prices of this equipment can increase significantly. This creates

additional financial pressure on hospitals and healthcare institutions, which must spend more to acquire the necessary PPE.

- **Supply Chain Disruption Risks:** The lack of a diverse network of accessible suppliers makes hospitals and healthcare institutions more susceptible to supply chain disruptions. A single failure at one link in the chain can result in delays or shortages of PPE, hampering the ability to provide healthcare.

To mitigate these problems, it is essential that hospitals and healthcare institutions establish diverse and reliable supplier networks, both locally and globally. This involves identifying alternative sources of supply, establishing partnerships with trusted suppliers, and creating strategic stocks of PPE. An accessible and resilient supplier network is essential to ensure that healthcare institutions can weather crisis situations and maintain an adequate supply of PPE to protect their staff and patients.

4. Conclusion

Comprehensive analysis of data and factors related to the purchase of and demand for PPE in hospital settings during health crisis reveals several challenges and complexities. These challenges not only impact the ability of hospitals to ensure the protection of their professionals and patients, but also highlight the importance of efficient supply chain management and strategic planning to face emergency situations.

Analysis of the data presented in the tables highlighted the significant increase in demand for PPE, especially during the COVID-19 pandemic, reflecting the direct impact of the crisis on the need for protective equipment. The acquisition of these PPE faces challenges such as bureaucracy, regulations, approval processes and extended deadlines, which can result in delays in product availability.

The need for increased safety stocks was also highlighted, as the bureaucracy and uncertainty associated with PPE procurement can lead hospitals to take a cautious approach to ensuring there are sufficient supplies in emergency situations.

Furthermore, the analysis showed that the lack of an accessible supplier network is the root cause of the problem. Reliance on a limited number of suppliers, global competition for resources, dependence on imports, and vulnerability to unreliable suppliers increase the risks of supply chain disruptions and PPE shortages.

In the face of these challenges, it is crucial that hospitals and healthcare institutions adopt strategic approaches to supply chain management, including diversifying the supplier network, establishing safety stocks, collaborating with government entities, and creating management plans as crisis response. Additionally, public awareness about the responsible use of PPE and education about proper

purchasing and use practices are critical to preventing panic buying and ensuring equitable access to this equipment.

Effective management of PPE procurement in hospital settings requires a multifaceted approach that considers not only growing demand, but also bureaucratic challenges, the need for safety stocks, and the creation of an accessible and resilient supplier network. These measures are essential to ensure the protection of healthcare professionals, the continuity of healthcare and the effective response to public health crises.

The knowledge generated by this research has the potential to inform crisis response strategies and policies, both locally and globally, highlighting the importance of preparedness, supplier network diversification, and collaboration between healthcare institutions and government authorities.

In future research, a promising area of study would be the efficiency of PPE distribution, where delivery routing, reverse logistics and storage strategies could be investigated to improve the speed and effectiveness of PPE delivery. Furthermore, the application of technological innovations in inventory management, such as blockchain and the Internet of Things (IoT), can be explored to improve traceability and demand forecasting. Supply chain resilience is another relevant area, examining how supplier diversification, implementing safety stocks, and creating business continuity plans can strengthen the ability to respond to health crises.

Other important topics include the economic and financial impact of healthcare crises, sustainability in the procurement of PPE, consumer behavior in times of crisis, international cooperation in the procurement of PPE, and public education strategies to promote the responsible use of PPE equipment. All these areas of research have the potential to contribute significantly to improving supply chain management and the availability of PPE in emergency situations.

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