

IMPROVING PHARMACEUTICAL SUPPLY CHAINS IN HUMANITARIAN SETTINGS

LITERATURE SEARCH ON SUPPLY CHAIN MANAGEMENT INNOVATIONS FOR PHARMACEUTICAL AND
MEDICAL COMMODITIES IN HUMANITARIAN CRISES OR FRAGILE SETTINGS



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JSI
2733 Crystal Drive
4th Floor
Arlington, VA 22202
Phone: 703-528-7474

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INTRODUCTION

This literature search focused on supply chain management advances and innovations for pharmaceutical and medical commodities in humanitarian crises or fragile settings. The goal was to examine how supply chain management strategies have addressed health and medical supply chain challenges brought about by recent emergency and crisis situations around the world. By looking at examples of innovative approaches to supply chain management, this search also uncovered practices and technologies that will likely be used in the future to manage supply chain disruptions.

The search included literature from March 2020 onward. During this period, much of the research related to health supply chain management focused on the COVID-19 pandemic and its effects, and pandemic-related documents therefore dominate the list of articles. The list includes peer-reviewed publications, journal articles, gray literature, and other supply chain and logistics literature. The following search terms were used to find relevant sources:

- Coordination to deliver health products
- COVID-19
- Disruptions in supply chain
- Emergencies
- Forecasting
- Green logistics
- Humanitarian disaster
- Humanitarian crisis/crises
- Health supplies
- Importation
- Information systems
- Inventory control strategies
- Logistics
- Logistics innovation
- Logistics management information system
- Pharmaceutical and medical commodities
- Risk management
- Quality assurance methods
- Reverse logistics
- Temperature control
- Transportation to the last mile
- Transportation during crisis
- Last mile delivery
- Remote management
- Availability of supplies in refugee camps
- Migration and emergency response
- Medical needs-assessment
- Quantification of needs
- Supply chain management
- Supply planning
- Supply chain visibility
- Humanitarian development nexus + logistics

ARTICLE SUMMARIES

Abdul Rahman NA, Ahmi A, Jraisat L, et al. 2022. **Examining the trend of humanitarian supply chain studies: pre, during and post COVID-19 pandemic.** *Journal of Humanitarian Logistics and Supply Chain Management*, 12 (4) 594–617. <https://doi.org/10.1108/JHLSCM-01-2022-0012>

This article covers publication trends of humanitarian supply chains before, during, and after COVID-19 by using bibliometric analysis. The authors used the Biblioshiny app, a shiny app for the Bibliometrix R package that decodes humanitarian supply chain data extracted from the Scopus database from 2006 to early 2022. The article goes into significant technical detail about the Biblioshiny tool and how it was used to analyze 644 Scopus articles. The results are distilled into figures showing top keywords, most productive sources, top publishing institutions, top publishing countries, most productive authors, and top cited articles. Based on analysis of those data points, there are three thematic areas among the papers: humanitarian logistics, humanitarian organizations, and humanitarian operation, with humanitarian logistics being the largest theme. There is also a comparison between leading themes in 2006 and those during and post-COVID-19 with the number of main themes moving from nine to eight as the decision support system theme in 2006 was absorbed into several new categories. The authors note that there are a few limitations of the study including the existence of previous bibliometric analyses of supply chains in certain industries like automotive, green, agriculture, and technology, but they vary widely in the databases they searched and the tools they used to analyze the data. The authors also note that policy perspectives are missing from this study and that this is an area that warrants further study. The article concludes with suggestions for future research.

Ahmadi, E, Mosadegh, H, Maihami, R et al. 2022. **Intelligent inventory management approaches for perishable pharmaceutical products in a healthcare supply chain.** *Computers & Operations Research*, 147. <https://doi.org/10.1016/j.cor.2022.105968>

This article describes intelligent inventory management (IIM) approaches for managing perishable pharmaceutical products in a health care supply chain. Managing inventory of these commodities is extremely challenging because of their perishable nature, consumer need, uncertain market conditions, storage requirements, and price. New IMM approaches are needed because existing inventory policies fail to account for various real-world issues including random demand and the nature of perishables. The authors propose a machine learning model that can mitigate some of these problems with its flexibility. Their design uses two algorithms to determine near-optimal inventory policies and compares them with existing methods. The article goes into detail about the mathematical formulas used and the reasoning behind them. Part of this study includes implementation of the design and training processes. Results of the implementation indicate that the IIM approaches can lead to lower costs and less risk of stockouts.

Akpan I, Udoh P, and Adebisi B. 2020. **Small business awareness and adoption of state-of-the-art technologies in emerging and developing markets, and lessons from the COVID-19 pandemic.** *Journal of Small Business & Entrepreneurship*, 34. <https://doi.org/10.1080/08276331.2020.1820185>

This article outlines new technologies, including internet and telecommunications, which small- and medium-scale businesses (SMEs) in emerging markets and developing economies can use to increase their market share and improve their business models. Many of the technologies are not new, but have been out of reach of these SMEs due to technological and/or monetary constraints. Larger businesses and more advanced economies switched to online technologies as soon as the pandemic started, but SMEs were unable to capitalize on the new internet space because of a lack of infrastructure. Now that the pandemic has waned, SMEs can begin to use technologies that will allow them to compete in the upcoming fourth industrial revolution (industry 4.0 or I4.0) like internet, artificial intelligence (AI), internet of things, cloud computing, big data analysis, and blockchain. The special issue, of which this article is a part, contains four articles that describe different technologies. The first article discusses financial innovation like ATMs, point of sales, internet banking, and mobile money tools, and how they can improve productivity. The second article introduces an algorithm for weighing different maintenance practice innovations and how they can improve resource management. The third article looks into process innovation and determines that it is the most important area for attaining high growth in startups. The last article investigates how effective innovative technology transfer is based on data from over 1,100 manufacturing firms in Africa. The conclusion is that countries should look inward for innovation rather than relying on help that may never appear. SMEs in emerging markets and developing economies face several challenges to development and implementation of new technologies including lack of infrastructure, money, government interest, technical capacity, decision-making, and education.

Alani AH, Miller L, Waweru I, et al. 2023. **Lessons learned from implementing the Non-Communicable Diseases Kit in a humanitarian emergency: An operational evaluation in Sudan.** *BMJ Global Health*, 7 (Suppl 5). <https://doi.org/10.1136/bmjgh-2023-012077>

This article evaluates the use of the WHO Non-Communicable Diseases Kit (WHO-NCDK) in primary health care settings in Sudan. The WHO-NCDK is a health system intervention aimed at providing supplies to manage NCDs in emergency settings, allowing for continuity of care during supply chain disruptions. Researchers applied this toolkit in Sudan to evaluate its effectiveness and to identify contextual factors that may influence the ability to apply this tool in crisis settings and situations. This study identified several key factors that influence the kit's effectiveness: local communities' unfamiliarity with health care facilities, the national integration of NCDs into primary health care (PHC), and the existence of monitoring and evaluation systems. For the kits to be most effective, health facilities must have adequate staff and resources. Researchers concluded that the WHO-NCDK can be a useful tool in crisis settings where health care resources are limited as long as these contextual factors are taken into account and addressed before the kit is implemented.

Atek S, Bianchini F, De Vito C, et al. 2023. **A Predictive Decision Support System for Coronavirus Disease 2019 Response Management and Medical Logistic Planning.** *Digital Health* 9. <https://doi.org/10.1177/20552076231185475>.

This article describes examples of logistics planning from the Earth Cognitive System for Coronavirus Disease 2019 project. This project consisted of a decision support system created to support health care institutions in monitoring and forecasting activities by using artificial intelligence (AI), social media analytics, and geospatial data. This system was able to use machine learning and AI to predict factors such as the number of emergency room visits and to identify high risk regions.

Beasley, K. 2022. **Covid-19 Altered The Supply Chain—Does Your Forecasting Strategy Reflect The New Reality?** *Forbes Innovation (blog)*. July 14, 2022. <https://www.forbes.com/sites/forbestechcouncil/2022/07/14/covid-19-altered-the-supply-chain-does-your-forecasting-strategy-reflect-the-new-reality/?sh=2e95f2875e24>

This article explores the COVID-19 pandemic's impact on the use of predictive analysis in supply chains. The pandemic caused stockouts of supplies around the globe, leading to a major increase in corporations' analytics spending to prevent future over- and under-stocking. Manufacturers also pivoted during the pandemic to reflect supply and demand trends, with many factories producing personal protective equipment (PPE) in place of their usual products. The author recommends four strategies for companies to adapt to changes in the supply chain: expand data sets to include external sources; build contract agreements directly with suppliers; look for non-traditional suppliers; and leverage technology to support data and analytics.

Brody B. 2020. **4 high-tech tools Johnson & Johnson is using to get products to you during the pandemic.** *Content Lab (U.S.)*. <https://www.jnj.com/innovation/johnson-johnson-supply-chain-technology-during-coronavirus>

This news update from Johnson & Johnson (J&J) describes the company's innovative practices to ship their products to consumers during the pandemic. The first measure J&J took was to start running plants around the clock and to focus on reducing complex formulations for simpler ones that would help the most people. The company also employs algorithms that flag anomalies in ordering levels so that they can be investigated. In order to manage varying staffing levels due to employee illness, J&J used an automated risk simulation to predict worse-case scenarios and then planned to mitigate them. Another issue exacerbated by the pandemic was product delivery. J&J used track-and-trace sensors to continually monitor where each shipment was and track timeline and delays. The last thing J&J did in the face of no international travel was to employ smart glass technology so that engineers could actually see what workers were seeing anywhere in the world and keep production running.

Budd J, Miller BS, Manning EM, et al. 2020. **Digital technologies in the public-health response to COVID-19.** *Nature Medicine*, 26 (8), Article 8. <https://doi.org/10.1038/s41591-020-1011-4>

This review captures digital innovations that emerged during COVID-19 along with their barriers to implementation and the technology limitations in regard to public health. The technologies discussed include machine learning, survey apps, and websites; wearable sensors and other devices; smartphone apps and phone-location data; social media and search engines; and teleconferencing. The authors outline each public health need, the technology that can help fulfill it, examples of where it has been used, and the limitations of the technology. Machine learning can help with epidemiological surveillance by pulling data from apps and websites, wearable sensors and other devices can help with case identification, apps and location data can help reduce area transmission, social media and search engines can help with public communication, and teleconferencing can help with telemedicine. Some limitations include the inability to sync data from all the different platforms, over-reliance on digital information which can be misleading, lack of consistent up-to-date data, and selection bias. The authors conclude that system owners and technology companies need to be involved in preparedness and alignment with international strategies to prevent future pandemics.

Cárdenas AM & Roger-Dalbert C. 2022. **Learning from Agility, Partnership and Innovation During the Covid-19 Pandemic: A Perspective From Industry.** *Frontiers in Cellular and Infection Microbiology*, 12. <https://doi.org/10.3389/fcimb.2022.838565>

This article examines the effects of the COVID-19 pandemic on the medical technology/device industry. It discusses the rapid changes and adaptations that took place so that certain workers in this industry could work from home, as well as accommodations made to physical workplaces to reduce the spread of the virus for employees whose jobs required them to be in-person. The authors identify three key areas of importance in this field as agility, partnership, and innovation. The article found that by utilizing those three skills, the industry was able to rapidly adapt to address the changing industry landscape brought on by the pandemic. However, work still needs to be done to better communicate to the public how and when they should be using different types of COVID-19 tests. Further strengthening of partnerships between different health stakeholders, including health care providers, academics, and public health agencies will help monitor infectious diseases and improve the outcome of future events.

de Rubalcava A de NG, Piñeiro OS, Jiménez RM, et al. 2023. **Modeling Population Movements under Uncertainty at the Border in Humanitarian Crises: A Situational Analysis Tool.** *arXiv* (arXiv:2303.15614). <https://doi.org/10.48550/arXiv.2303.15614>

This article describes the development of a situational analysis tool that helps predict the flow of populations crossing borders in humanitarian emergencies. The tool is specifically designed to work with the United Nations High Commissioner for Refugees (UNHCR) model by predicting the number of migrant and forcibly displaced populations during crisis events. This tool was developed and applied in the context of the Venezuela-Brazil border crisis, when the border between these countries was closed due to the

COVID-19 pandemic. This event showcased the need for a tool to estimate what size populations might be expected to cross the border during crisis events. The tool consists of three main components: a collection of real-time data of potential indicators of interest in crossing the border; a model to predict how many people might cross the border based on past crossings and other indicators; and an interactive simulation tool that models the flow of people crossing the border to predict the needed shelter capacity. The authors of this study hope to continue to improve this tool for use in future crisis settings and ultimately expand its use to forced displacement contexts as well.

Dubey R. 2022. **Design and management of humanitarian supply chains: Challenges, solutions, and frameworks.** *Annals of Operations Research*, 319(1), 1–14. <https://doi.org/10.1007/s10479-022-05021-7>

This article examines 44 articles on the topic of humanitarian supply chains and synthesizes the results to note gaps in the current research and recommend areas for future studies. It describes the recent rise of the field of humanitarian supply chains to address disasters, beginning with the poor response to the 2004 Indian Tsunami, and provides a brief summary of the key topics found in the articles included in the review. The author argues the need for a multi-methods approach and points out the gap in the literature surrounding this topic, including coordination between organizations, technology and human interaction, innovation, and crisis leadership.

Elrha. 2021. **Field Ready: Making humanitarian supplies in the field.** <https://www.elrha.org/project/field-ready-scale/>

This source summarizes the Field Ready project, which aims to improve humanitarian logistics and supply chains by using technology, specifically 3D printing. It explains that using additive manufacturing in the form of 3D printing directly in the field reduces costs and wait times for communities to receive needed supplies. The project aims to further scale up this approach by moving these manufacturing processes to areas where they are most needed and by providing training to others to use these skills and technologies.

Falagara Sigala I, Kettinger WJ, and Wakolbinger T. 2020. **Digitizing the field: Designing ERP systems for Triple-A humanitarian supply chains.** *Journal of Humanitarian Logistics and Supply Chain Management*, 10 (2), 231–260. <https://doi.org/10.1108/JHLSCM-08-2019-0049>

This study's goal was to determine the design principles needed in enterprise resource planning (ERP) systems for humanitarian organizations to optimize supply chains. The introduction notes that humanitarian organizations often work in complex and unpredictable environments, and that supply chains must be able to adapt quickly to meet these needs. However, their current systems and technology are often not capable of meeting these standards. The optimal supply chain is one that displays agility, adaptability, and alignment (Triple-A). ERP systems can help humanitarian organizations achieve these three components and lead to successful humanitarian relief efforts by enhancing integration, communica-

tion, and decision-making. The authors of this paper conducted a case study in which they engaged in ERP design for the humanitarian organization Medecins Sans Frontieres (MSF) and monitored the results of the design and implementation process. The study found that ERPs need to be designed as unique systems to meet the needs of specific humanitarian organizations. Each organization has different needs and faces different challenges, particularly related to field-level work, and standard ERP packages do not meet these needs. One key challenge was the decentralized nature of humanitarian organizations that often have offices or locations around the world and in remote locations that require both the ability to connect between systems and the ability for systems to work autonomously. The authors ultimately recommend that humanitarian organizations looking to implement ERPs review their own specific needs and processes and consider using unique design principles to develop their software system, rather than using an existing ERP package.

Flynn B, Cantor D, Pagell M, et al. 2020. **From the Editors: Introduction to Managing Supply Chains Beyond Covid-19 – Preparing for the Next Global Mega-Disruption.** *Journal of Supply Chain Management*. <https://doi.org/10.1111/jscm.12254>

This article summarizes a special issue of the *Journal of Supply Chain Management* focusing on the importance of effective supply chain management in light of the COVID-19 pandemic and how the field can move forward to prepare for the next major disruption. The authors state that this issue features essays that discuss learnings from the COVID-19 crisis, such as the fact that the disruption of global supply chains for an extended period of time highlighted the need for renewed supply chain risk management strategies. They also note that some articles focus on how the pandemic led to certain improvements that can be leveraged going forward, such as rapid adoption of communication and sharing technologies, reduced time and costs spent on travel, and expanded production of life-saving medicines by pharmaceutical companies. Together, the articles in this issue provide an overview of the field of supply chain management in the wake of COVID-19 and suggest areas for future research.

Foster T, Patel P, and Skiba K. 2021. **Four ways pharma companies can make their supply chains more resilient.** <https://www.mckinsey.com/industries/life-sciences/our-insights/four-ways-pharma-companies-can-make-their-supply-chains-more-resilient>

This article outlines four ways that pharmaceutical companies can make their supply chains more resilient as they become increasingly global and complex. The authors explain that the potential for disruption that comes with operating at such a large scale puts companies at risk for major losses. The first way to increase supply chain resilience is end-to-end transparency. Companies should have a clear picture of all of the small moving parts that make up their supply chains in order to identify potential risks and vulnerabilities. The second way to increase resilience is routine stress-testing and reassurance, which can be done by using scenario planning and modeling to simulate the impact of potential issues and plan for solutions. The third is reduced exposure to shocks, such as by expanding the network of suppliers, improving physical assets to withstand natural disasters, and preparing for quick changes and rerouting in case of issues with one supplier or site. The final recommendation for increasing resilience is having

supply chain resilience on the executive agenda. Organizations should use existing forums to conduct risk assessments or create a specific committee or working group dedicated to assessing and managing supply chain risks.

Gao Y, Gao H, Xiao H, et al. 2023. **Vaccine Supply Chain Coordination Using Blockchain and Artificial Intelligence Technologies.** *Computers & Industrial Engineering* 175 (January). <https://doi.org/10.1016/j.cie.2022.108885>

This article examines the use of blockchain and artificial intelligence (AI) technology in vaccine supply chains to address issues of vaccine reliability and accessibility. Blockchain technology tracks shipments across the supply chain and traces items as they move through the production and distribution process. The use of blockchain technology in vaccine supply chains can ensure that vaccines are safe and have not been tampered with at any point, thus addressing the issue of vaccine reliability. AI can quickly analyze large amounts of data and provide recommendations based on the results. This technology can be applied to vaccine supply chains in many ways, such as by analyzing the efficiency of the supply chain and by looking at data outside of the supply chain to predict future supply and demand. The authors conclude that these technologies can improve transparency, safety, and efficiency in vaccine supply chains.

Goodarzian F, Taleizadeh AA, Ghasemi P, et al. 2021. **An integrated sustainable medical supply chain network during COVID-19.** *Engineering Applications of Artificial Intelligence*, 100, 104188. <https://doi.org/10.1016/j.engappai.2021.104188>

This article describes the development of a mathematical formulation called Sustainable Medical Supply Chain Network aimed at addressing the urgent need for sustainable supply chains brought to light by the COVID-19 pandemic. This formula takes into account three key components of sustainability: economic, environmental, and social effects. It aims to maximize positive features of supply chain development such as job creation and economic development while minimizing costs such as transportation and carbon emissions. The authors tested this formula using three meta-heuristic algorithms with different parameters. They then assessed the results of each algorithm to determine which displayed the most successful result.

Harland C. 2021. **Discontinuous Wefts: Weaving a More Interconnected Supply Chain Management Tapestry.** *Journal of Supply Chain Management*, 57(1), 27–40. <https://doi.org/10.1111/jscm.12249>

The author of this study proposes that to tackle future crises similar to the COVID-19 pandemic, the field of supply chain management (SCM) should take a more interconnected approach by considering supply markets, public procurement, humanitarian SCM, network and systems thinking, and global stewardship. The introduction points out that even countries that were relatively well-prepared for a pandemic event prior to COVID-19 still were not able to implement their plans fully and effectively. The idea of interconnectedness as a key factor in supply chain resilience is not new, but has not yet been integrated into existing

systems. The article then discusses four sub-topics regarding the role of supply chains in the COVID-19 crisis: the lack of knowledge of supply markets early on in the pandemic, the lack of research on public sector SCM, the current focus on firm-based decision-making, and whether it is feasible to form a global supply chain response to address future crises. The author argues that humanitarian supply chains are already adept at handling complex networks of organizations and resources, particularly during times of crisis, and that the broader field of SCM should look to humanitarian supply chains for guidance on how to increase interconnectedness.

Heckmann A. 2022. **Industry Innovation: Turning Supply Chains into Hot Spots for Meaningful Change.** SAP News Center.

This article summarizes three of SAP's recent projects in the SCM field. The first is the SAP Information Collaboration Hub for Life Sciences, a network that allows pharmaceutical companies to share product information across different levels of the supply network. The goal of this network is to reduce the existence of counterfeit drugs by ensuring that medications are traceable and verifiable across the supply chain. The second project is the SAP Intelligent Clinical Supply Management solution. This project aims to address the barriers present in traditional supply chain structures by providing accurate information on demand and stock levels at different sites, allowing for faster supply cycle times and fewer inventory overages. The third project is the SAP Multi-Bank Connectivity solution that works to improve relationships between companies and banks. This digital system provides a channel between banks and companies, allowing them to transfer data and payments remotely, increasing efficiency and transparency.

Hu H, Xu J, Liu M, et al. 2023. **Vaccine Supply Chain Management: An Intelligent System Utilizing Blockchain, IoT and Machine Learning.** *Journal of Business Research* 156 (February). <https://doi.org/10.1016/j.jbusres.2022.113480>

This article describes a new system for managing vaccine supply chains that addresses the three major issues in the field: vaccine quality, demand forecasting, and trust among stakeholders. Their system tackles these problems by using blockchain technology, the Internet of Things (IoT), and machine learning. The authors note that this system is original and no other vaccine supply chain management in the literature uses multiple digital technologies. Blockchain technology and the IoT address issues of vaccine quality by tracking products with real-time data as they move along the supply chain. The system also uses machine learning to predict demand and improve distribution, transportation, and inventory management. The authors conclude that combining multiple digital technologies into one system helps to solve the three major issues in vaccine supply chain management.

Hu Z, Sarfraz M, Khawaja KF, et al. 2022. **The Influence of Knowledge Management Capacities on Pharmaceutical Firms Competitive Advantage: The Mediating Role of Supply Chain Agility and Moderating Role of Inter Functional Integration.** *Frontiers in Public Health*, 10. <https://doi.org/10.3389/fpubh.2022.953478>

This article examines how knowledge management (KM) capacities can improve pharmaceutical companies' supply chain agility, making them more competitive in the field. KM is defined by the authors as "a set of dynamic capabilities of a firm to gather valuable information and then send it across the units of the firm to improve operations internally." The study examines several KM capacities: absorptive capacity, transformative capacity, and inventive capacity. The authors then attempt to identify the influence of these three capacities on overall competitive advantage. They determined that having these KM capacities gives a company more supply chain agility and allows them to quickly respond to changes in the market, which thereby gives them greater competitive advantage. The study concludes that KM is an essential resource for a pharmaceutical firm's competitive advantage and overall success. The more a firm invests in their KM capacities (absorptive capacity, transformative capacity, and inventive capacity) the better their performance and supply chain agility will be.

International Medical Corps. 2022. **Pharmaceutical Innovation Is Making a Difference in South Sudan.** <https://internationalmedicalcorps.org/story/pims-south-sudan/>

This article examines the use of the Pharmaceuticals Information Management System (PIMS) in South Sudan. PIMS is a software system that allows medical and pharmaceutical staff to manage supplies and equipment to improve supply chains. At the Juba camp for internally displaced persons (IDP), PIMS allowed the pharmacy facility to shift from manual record keeping and paper records to electronic records management. PIMS also automated this pharmacy's inventory records and prescription refills. Pharmacy staff reported that this change greatly improved the quality of pharmacy services as it allowed staff more time to interact directly with patients and less time spent manually updating records. While this system is currently used in pharmacies, hospitals, and health care centers, International Medical Corps is planning to expand the use of PIMS to humanitarian agencies and other organizations going forward.

International Rescue Committee. N.d., retrieved January 4, 2024. **Medicine Bank.** <https://airbel.rescue.org/projects/medicine-bank/>

Medicine Bank is a supply chain management solution that allows low-income patients with chronic illnesses to purchase medications at a discounted price. This project, currently in the prototype stage, works by connecting pharmaceutical producers directly with local pharmacies to sell medications with an approaching expiration date for a discounted price. Pharmacies can then provide these discounted medications to their low-income clients at a reduced price. This is also beneficial for producers as they would have to pay to get rid of the expired medications, whereas they can instead profit from them. This project will initially be piloted with medications that treat chronic illnesses as demand for these tends to be more predictable, but a similar system could be applied to other medicines or supplies in the future.

Ivanov D. 2021. **Supply Chain Viability and the COVID-19 pandemic: A conceptual and formal generalisation of four major adaptation strategies.** *International Journal of Production Research*, 59 (12), 3535–3552. <https://doi.org/10.1080/00207543.2021.1890852>

This study describes four major strategies to maintain supply chains during future pandemics: intertwining, scalability, substitution, and repurposing. It also introduces a model to analyze the results of deploying these four strategies and describes case studies where these adaptations were implemented. The authors note that, since the COVID-19 pandemic, many papers have been published that attempt to explain the effects of the pandemic on global supply chains and suggest solutions for future crisis events. However, there is a research gap around using the four adaptation strategies together and measuring their results. The article provides examples of several case studies that utilized one or more of these strategies effectively during COVID-19. For example, Amazon displayed scalability by increasing their workforce, opening new grocery pick up locations, and prioritized stocking and delivering essential items such as medical supplies and groceries to meet increased demand. Johnson & Johnson also used scalability by drawing from their past experience providing supplies in disaster settings and using simulated scenarios to predict potential challenges and determine solutions, which allowed them to ensure stock of high-demand items. AGRO corporation, an agricultural equipment manufacturer, used substitution by adapting risk management strategies they had employed during previous supply chain disruptions, for example using unconventional delivery methods or routes to ensure timely delivery. Noting the shortage of protective equipment for health workers, Ford repurposed some of its manufacturing capacity to produce PPE such as mylar face shields. The authors conclude that using a combination of these four strategies in an integrated framework of viability can help mitigate future supply chain disruptions.

Karabacak Z and Saygili MS. 2022. **Green Practices in Supply Chain Management: Case Studies.** *Journal of Business and Trade*, 3 (1), Article 1.

This article evaluates the effects of using green practices in supply chain management by examining the literature around the topic as well as several case studies. Recent research has shown that some companies have switched to using green practices reactively in order to comply with legal requirements. However, those that change their practices proactively to mitigate their effect on the environment find that there is a direct link between their ecological performance and their economic performance. Companies using green supply chain management often see reduced costs for operations and logistics and increased customer satisfaction. Implementing green practices can require upfront investment, which may be manageable for larger companies but can be difficult for smaller organizations. The authors describe several ways that green practices can be incorporated across supply chains, including in production, marketing, packaging, transportation, and more. The article looks at case studies of several companies that have implemented green supply chain management and how this has affected their business. For example, IKEA took several steps to become greener, including recycling old products into raw materials and using recycled materials to manufacture new products. Correlating with these changes, the company has seen a rise in sales, possibly demonstrating that using green practices increases customer satisfaction with the brand. Other companies saw a reduction in their energy consumption and water use after changing their supply chain processes. The authors conclude that although implementing green supply chain management requires upfront investments, companies that make these changes reduce their

costs over time, increase their efficiency, and gain a competitive advantage, in addition to improving their impact on the environment.

Koç E and Türkoğlu M. 2022. **Forecasting of Medical Equipment Demand and Outbreak Spreading Based on Deep Long Short-Term Memory Network: The COVID-19 Pandemic in Turkey.** *Signal, Image and Video Processing* 16 (3): 613–21. <https://doi.org/10.1007/s11760-020-01847-5>.

This study presents a tool to forecast the demand for medical equipment during the COVID-19 pandemic based on a long short-term memory network. Researchers fed a set of COVID-19 data from the beginning of the pandemic into the system to train it to predict demand. They had the system predict the number of COVID-19 cases, beds in intensive care, and respiratory supplies for a specific period, and then compared the predictions to the real figures. In all three cases, the number the system predicted was very similar to the real-life numbers, showing that the model is highly accurate. This system is one of the first of its kind and has promising implications for demand forecasting in future crisis scenarios.

Kovács G and Falagara Sigala I. 2020. **Lessons learned from humanitarian logistics to manage supply chain disruptions.** *Journal of Supply Chain Management*. <https://doi.org/10.1111/jscm.12253>

This article notes the shared characteristics between pandemic supply chains and humanitarian response supply chains, including unpredictable demand, lack of resources, and poor infrastructure, and describes lessons learned from humanitarian supply chain contexts that could be applied to mitigate future supply chain disruptions in other sectors. Neither governments nor industries were adequately prepared for the disruptions caused by the COVID-19 pandemic, and the author notes that pandemics are not the only type of event that can cause these large-scale interruptions. Humanitarian supply chain management offers a wealth of experience in managing these issues and adapting quickly during times of crisis. One key element is preparedness, not just by stocking adequate resources, but by training and modeling crisis events and responses ahead of time across every level of the supply chain. Agility and the ability to quickly make decisions is another important factor: humanitarian supply chains strive to move with urgency while also using needs assessment tools to determine the most effective course of action. They are also willing to think outside the box and come up with innovative solutions to meet unexpected challenges, such as in the case of manufacturers diverting their resources to make PPE and other medical supplies during the COVID-19 pandemic. Companies also need to collaborate across sectors and between the public and private sectors to improve their response to future crises. The author stresses the importance of being prepared for future supply chain disruptions that could come from a number of sources, including climate change, political conflict, financial crises, and more.

Kumar P, Singh RK, and Shahgholian A. 2022. **Learnings from COVID-19 for managing humanitarian supply chains: Systematic literature review and future research directions.** *Annals of Operations Research*, 1–37. <https://doi.org/10.1007/s10479-022-04753-w>

The authors of this article examine the existing literature on lessons from COVID-19 for managing humanitarian supply chains and suggest directions for future research. The findings from their literature show several of the major challenges created by COVID-19 and how those were mitigated using humanitarian supply chain strategies. Some of the major challenges identified in their review include lack of planning and preparedness, extended shortages, inadequate lab capacity, lack of supply of vaccines, and low vaccine uptake. The pandemic provided several learnings for managing humanitarian supply chains going forward. One of the most critical is the importance of preparedness and planning in supply chains. Another learning was the need for prepositioning relief items and ensuring adequate supply. Coordination and collaboration among and across different stakeholders is also a key component of effective supply chain management. The article identifies several areas in need of further research, including how data analytics can be used to predict future pandemics or other disruptive events, and how to use emerging technologies more effectively to better manage humanitarian supply chains.

Kwapong Baffoe BO and Luo W. 2020. **Humanitarian Relief Sustainability: A Framework of Humanitarian Logistics Digital Business Ecosystem.** *Transportation Research Procedia*, 48, 363–387. <https://doi.org/10.1016/j.trpro.2020.08.032>

This study uses a literature review to develop a Humanitarian Logistics Digital Business Ecosystem (HLD BE) framework that can address common challenges that humanitarian supply chains face and sustain their logistics operations. The authors describe several common challenges in humanitarian logistics, including lack of funding, duplication of efforts, information availability, transparency, and coordination. A digital business ecosystem is a concept that involves businesses acting like biological ecosystems by creating a collaborative network that works together and shares resources and information. The authors propose applying a similar approach to humanitarian logistics to form an HLD BE, which would leverage data analytics and bring together humanitarian logistics stakeholders and business stakeholders and foster collaboration. The paper proposes several ways that such a structure could benefit disaster relief efforts, but also notes that there is no empirical evidence to support this claim. The authors suggest future studies could be done to test this framework and prove the effectiveness of an HLD BE.

Lal A, Lim C, Almeida G, et al. 2022. **Minimizing COVID-19 disruption: Ensuring the supply of essential health products for health emergencies and routine health services.** *The Lancet Regional Health – Americas*. [https://www.thelancet.com/journals/lanam/article/PIIS2667-193X\(21\)00125-3/fulltext](https://www.thelancet.com/journals/lanam/article/PIIS2667-193X(21)00125-3/fulltext)

This article argues that supply chains should use multi-country procurement in order to increase access to essential medicines and health supplies and to respond to future health emergencies like the COVID-19 pandemic. The authors examine the results of the Pan American Health Organization's (PAHO) Strategic Fund to show that partnerships between companies across different countries can minimize supply

chain disruptions by reducing the effects of stockouts. As of 2021, PAHO had agreements with 50 countries, territories, and public health institutions, making it uniquely positioned to provide a diverse range of services and support to its members. The strategic fund delivers on five key areas: technical cooperation, pooled procurement, capacity-building, quality assurance, and innovative financing. The article concludes that multi-country pooled procurement systems like PAHO's Strategic Fund can help countries maintain supply chains during future disruptive events, including pandemics, creating a more resilient and sustainable global system.

Lin Q, Zhao Q, and Lev B. 2020. **Cold chain transportation decision in the vaccine supply chain.** *European Journal of Operational Research*, 283 (1), 182–195. <https://doi.org/10.1016/j.ejor.2019.11.005>

This paper examines the connection between vaccine distributors' decisions to use cold chain in transportation and retailers' inspection processes upon arrival. The authors examine the existing literature on the subject to develop a basic model that describes the conditions that may cause a distributor to choose to adopt cold chain transportation or not. Factors that affect this decision include cost of implementing cold chain throughout transportation, potential loss due to a vaccine-related adverse event, and potency of the vaccine. This model reveals that having a retailer perform an inspection of the product at the end of the transportation process increases the likelihood of the distributor using cold chain. The authors then compare the effectiveness of a one-step versus two-step inspection by the retailer. The study concludes that the one-step inspection has a stronger influence on the distributor's decision to use cold chain.

Liu P. 2020. **Intermittent Demand Forecasting for Medical Consumables with Short Life Cycle Using a Dynamic Neural Network during the COVID-19 Epidemic.** *Health Informatics Journal* 26 (4), 3106–22. <https://doi.org/10.1177/1460458220954730>

This study describes a model that forecasts intermittent demand for medical consumables by taking into account seasonal factors that influence demand. Products like medical consumables have a very short life cycle, making it difficult to predict demand using typical factors such as historical sales data. Researchers tested various models using dynamic neural networks to determine the optimal model structure. They concluded that while this model is useful in predicting intermittent demand, the format of forecasted sales values (decimal or integer) in small data sets led to different results. While this is not an issue in large data sets, more research is needed to optimize a forecasting model for intermittent demand.

Marbough D, Abbasi T, Maasmi F, et al. 2020. **Blockchain for COVID-19: Review, Opportunities, and a Trusted Tracking System.** *Arabian Journal for Science and Engineering*, 45 (12), 9895–9911. <https://doi.org/10.1007/s13369-020-04950-4>

This paper reviews potential opportunities and applications of blockchain-based tracking systems in combating the COVID-19 pandemic. Many companies, both in the technology sector and in health care,

have developed contact tracing apps to track the spread of COVID-19, but this data may be imperfect or unreliable due to the potential for it to be hacked or manipulated. Using blockchain technology in this type of data tracking could allow for more reliability and accuracy. One potential use case is in clinical trial management, where blockchain could aid in recording clinical data from trial participants, ensuring accuracy and transparency. Another major area for use is in supply chain management, where blockchain technology can connect stakeholders in one network and help move operations along more quickly. Blockchain can also be used in several ways to track the spread of the virus, including in contact tracing through mobile apps and in databases that store up-to-date news and information, ensuring that fraudulent data cannot be added. The authors propose and evaluate a blockchain-based tracking system for logging data related to COVID-19 that would collect information from various web sources, including WHO, the Centers for Disease Control and Prevention, and the Institute for Health Metrics and Evaluation. They provide a cost analysis and security analysis of this system, highlight the benefits as well as the challenges associated with it, and propose that future research might focus on improving specific functionalities of the system.

Onyango G and Ondiek JO. 2022. **Open Innovation during the COVID-19 Pandemic Policy Responses in South Africa and Kenya.** *Politics & Policy* (Statesboro, Ga.), September. <https://doi.org/10.1111/polp.12490>

This article explored how the governments in South Africa and Kenya have used open innovation to address four aspects of the COVID-19 pandemic: economic recovery, logistics and supply chain, digital healthcare partnerships, and collaboration. In addition to several other innovations, the government of Kenya adopted transport modeling sensors to track vaccine temperatures across the supply chain. Kenya Airways invested in updated pharma warehouses and repurposed passenger flights to ship COVID-19 essentials. The South African government invested heavily in digital technologies that allowed for greater visibility and traceability in their supply chains. Both governments have increased their use of and funding for open innovation strategies in response to the pandemic.

Papalexio M, Bamford D, Nikitas A, et al. 2022. **Pharmaceutical supply chains and management innovation?** *Supply Chain Management*, 27 (4), 485–508. <https://doi.org/10.1108/SCM-12-2019-0456>

This study evaluates the effectiveness of innovative programs in pharmaceutical SCM to improve service provision. Innovations in pharmaceutical SCM could result in reduced waste, improve inventory control, and enhance the quality of health services. However, the complexity of pharmaceutical SCM and the fact that they tend to operate independently makes it difficult to implement innovative approaches and solutions. The researchers conducted interviews and used questionnaires in hospital and community pharmacies to assess the impact of innovations in pharmaceutical SCM environments. Responses highlighted the complexity of communication and knowledge sharing in these organizations, and their technology systems are typically not integrated. Participants also noted the difficulty of introducing new and innovative processes into a system that is currently inefficient. These findings led the authors to create the Innovative Pharmaceutical Supply Chain Framework. This framework would act as a guide to pharmacies and provide information on how to develop supply chain strategies to reduce waste and enhance service quality.

Patil A, Madaan J, Shardeo V, et al. 2022. **Material convergence issue in the pharmaceutical supply chain during a disease outbreak.** *The International Journal of Logistics Management*, 33 (3), 955–996. <https://doi.org/10.1108/IJLM-11-2020-0425>

This article explores the issue of unsuitable and inappropriate donations in pharmaceutical supply chains during disease outbreaks and strategies that can lessen the negative results of this material convergence problem. Material convergence problems cause a number of issues in supply chains, including wasted resources, congested networks, and delays. Unsuitable pharmaceuticals also have their own unique set of problems, as they can become an environmental hazard if not disposed of properly and can also be resold in unsafe ways. This study examines the literature on this topic to develop a problem-solving framework for pharmaceutical supply chains facing drug convergence issues. The authors used simulation modeling to explore several ways to implement circular economy principles in pharmaceutical supply chains to address these issues and improve performance. They also identify seven learnings related to inappropriate donations and seven actions to relieve these effects. The learnings and simulations described in this study can be used by decision-makers to identify interventions tailored to their specific needs.

Raj A, Mukherjee AA, Lopes de Sousa Jabbour AB, et al. 2022. **Supply chain management during and post-COVID-19 pandemic: Mitigation strategies and practical lessons learned.** *Journal of Business Research*, 142, 1125–1139. <https://doi.org/10.1016/j.jbusres.2022.01.037>

This article examines the supply chain challenges that manufacturers have faced as a result of the COVID-19 pandemic, focusing specifically on the context of India. Based on a literature review, the authors identify ten major challenges: uncertainty of demand, inconsistency of supply, scarcity of material, delay in delivery, suboptimal substitute adoption, scarcity of labor, suboptimal manufacturing, constraint in capacity, vehicle unavailability and delays, and last-mile delivery challenges. They rank the most prominent challenges in order to determine which issues need to be addressed most urgently, noting that inconsistency of supply and suboptimal manufacturing were the two most prominent challenges facing manufacturers. The study describes mitigation strategies based on these challenges, breaking them into short-term and long-term strategies. The authors suggest that future similar studies could be conducted in other countries to see if their challenges are similar or different. They also note that while this study focused on the context of manufacturing, other studies could be done to identify challenges in the service industry.

Rakhimova G and Spiller D. 2021. **WFP's COVID-19 Fast Track: Sourcing humanitarian innovation at speed and scale.** *Medium*. <https://wfpinnovation.medium.com/sourcing-humanitarian-innovation-at-speed-and-scale-wfps-covid-19-fast-track-f4012369fb37>

This article describes the World Food Programme's (WFP) COVID-19 Fast Track innovation challenge, which took place in South Sudan in response to high rates of food insecurity caused by supply chain disruptions. After identifying food insecurity as a major issue, the WFP put out an open call for innovations, requesting solutions that involved humanitarian supply chain elements and could be quickly implemented. This resulted in three innovative pilot projects: Retail in a Box, Cockpit, and Rainmaker. Retail in a Box, which has successfully run in Mozambique, brings pop-up retail stores to communities in need, combatting store closures and delivery delays in food supply chains caused by COVID-19. Cockpit provides data analysis

about WFP's school meal program, allowing for accurate and timely decision-making. Rainmaker noted South Sudan's pre-existing conditions for food growing, including long sunlight hours and large amounts of agricultural land, and tapped into this by installing solar-powered water pumps and sensor-driven drip irrigation systems in villages around the country.

ReliefWeb. 2023. **Ethiopia's First Long-Range Medical Drone Network Established.** <https://reliefweb.int/report/ethiopia/ethiopias-first-long-range-medical-drone-network-established>

Ethiopia has established its first medical drone network to deliver medical supplies, including vaccines, to remote and hard-to-reach areas. The 30-day project consisted of 44 total flights to six different communities. The drones fly along pre-planned routes which have been mapped out in advance to avoid any physical obstacles. For the most remote locations, the project established a battery-swap hub, allowing the network to reach as far as 240 km from the distribution center. The drones can also be used for two-way delivery, meaning that communities can use the drones to send samples back to more centrally located labs. Based on the success of this effort, the project has been extended to run for an additional 90 days in early 2024.

Sarigol I, Ozdemir RG, and Sarigol EB. 2022. **Covid 19 vaccine order allocation: An optimization model with substitution.** *Journal of Humanitarian Logistics and Supply Chain Management*, 13 (2), 125–139. <https://doi.org/10.1108/JHLSCM-09-2021-0094>

This paper examines the issues of supplier selection and order allocation in vaccine supply chains in the context of the COVID-19 pandemic with the aim of determining ways to minimize the postponement of vaccination plans. Governments need to consider several factors when determining the type and quantity of vaccines to order, such as vaccine effectiveness, storage conditions, supplier reliability, and community preferences. The authors of this article developed an optimization model for governments to choose vaccine plans that uses a weighted-sum approach to make decisions about vaccine orders and substitutions to avoid postponement of these plans. The three objectives included in the model are purchasing costs, postponed vaccinations, and ineffectively vaccinated people. The authors explore how this model might be used in optimum, most-likely, and pessimistic scenarios. This tool can be used by governments in their decision-making process to determine the best possible vaccine plan in different contexts while minimizing the possibility of postponement.

Sawik T. 2022. **Stochastic Optimization of Supply Chain Resilience under Ripple Effect: A COVID-19 Pandemic Related Study.** *Omega* 109 (June). <https://doi.org/10.1016/j.omega.2022.102596>

The COVID-19 pandemic caused several major disruptions to supply chains, including increased demand for health care products, shortage of material supplies, reduced availability of workers, and delays in transportation and distribution. These disruptions led to an increase in research on supply chain resili-

ience strategies, as well as a higher level of analysis known as supply chain viability. This is defined as the ability of supply chains to survive in difficult situations by reacting to challenges that arise and adapting to meet changing environments. The ripple effect refers to the fact that during the pandemic, disruptions persisted for a long period and spread through the entire supply chain. The study proposes a decision-making model for supply chains facing a similar situation.

Sayol I. N.d., retrieved September 21, 2023. **Humanitarian logistics: At the heart of every emergency.** <https://ignasisayol.com/en/humanitarian-logistics-at-the-heart-of-every-emergency/>

This article provides an overview of humanitarian logistics and its role in emergency and crisis response. The author explains that one major difference between humanitarian supply chains and commercial supply chains is the difficulty in forecasting for the latter due to the unpredictable nature of the setting it is working in. This makes adaptability and innovation extremely important in developing humanitarian logistics strategies. The author describes three recent technological innovations and how they are being implemented in this field: 3D printing, drones, and blockchain. As supply chain disruptions become the new norm due to factors such as climate change and pandemics, humanitarian logistics strategies will need to become increasingly adaptable to meet these challenges quickly and efficiently.

Schmalz F. 2020. **The coronavirus outbreak is disrupting supply chains around the world—Here's how companies can adjust and prepare.** *Business Insider*. <https://www.businessinsider.com/covid-19-disrupting-global-supply-chains-how-companies-can-react-2020-3>

This article describes the supply chain challenges caused by COVID-19 and the unique and innovative ways companies have addressed these issues. One solution is for larger companies to build regional supply chains, segmenting their production so if one location is not functioning, others may remain in operation. A solution for smaller companies that are not able to employ this approach is to lean on technology, specifically using 3D printing and smarter warehouse information systems. The author discusses the need for companies to look to the future and develop long-term strategies that take into account efficiency and resilience.

Siriwardhana Y, De Alwis C, Gür G, et al. 2020. **The Fight Against the COVID-19 Pandemic With 5G Technologies.** *IEEE Engineering Management Review*, 48 (3), 72–84. <https://doi.org/10.1109/EMR.2020.3017451>

This paper discusses the use of 5G and internet of things related technologies in combatting the effects of the COVID-19 pandemic. The authors describe several examples of how these technologies have been used in innovative ways across several different industries. One is through telehealth, where 5G technology allows for the transfer of health data from patients' wearable devices for smartphones directly to health care professionals. It can also be used to conduct virtual clinical services with high-quality audio and video. 5G technology has also been effectively used in contact tracing and monitoring self-isola-

tion. Internet of things technology has been used to electronically tag products, helping with supply chain management. While there are several promising examples of how these technologies have streamlined processes in multiple sectors, they come with challenges, including privacy and security issues, scalability issues, and connectivity issues. The authors propose potential solutions to each of these challenges, but note that further research may be needed to effectively address these concerns.

Spieske A, Gebhardt M, Kopyto M, et al. 2022. **Improving resilience of the healthcare supply chain in a pandemic: Evidence from Europe during the COVID-19 crisis.** *Journal of Purchasing and Supply Management*, 28 (5). <https://doi.org/10.1016/j.pursup.2022.100748>

This article examines evidence from Europe to suggest strategies for improving future resilience of health care supply chains based on experiences from the COVID-19 pandemic. The authors look at this issue through the framework of the Resource Dependence Theory, which states that no organization is self-sufficient and that organizations form relationships with others to access critical resources. Because these relationships cause dependence on an outside party, they become a source of risk for the organization. Therefore, companies, including those in the health care industry, need to manage their dependence on outside partners to reduce vulnerabilities. The authors examined several case studies from the COVID-19 pandemic to determine the circumstances that led to these inter-organizational dependencies and how various companies have dealt with problems that arose from these relationships. Two types of strategies were typically used to combat these issues: buffering, by which companies reduce their exposure to a partner to reduce dependency, and bridging, by which companies establish stronger bonds with a partner to increase their influence over them. Some of the strategies used in the case studies included establishing central warehouses for medical supplies, exchanging medical supplies between regions with different levels of demand, and securing medical supplies from suppliers outside their typical networks.

Stark. 2022. **Pharma Supply Chains of the Future.** EYGM. <http://ey.com>

This article reviews ways in which the pharmaceutical supply chain industry dealt with disruptions caused by the COVID-19 pandemic, gathering insights from 17 companies that are members of the Pharmaceutical Manufacturing Forum. Following the pandemic, there have been several policy changes from the US, the EU, and China aimed at rebuilding and strengthening supply chains to ensure that pharmaceutical and medical products are available during future crises. Prior to the pandemic, pharmaceutical supply chains were becoming increasingly globalized, but we are now seeing a trend toward localization and a greater focus on developing regional supply chain networks. The authors suggest that localization combined with other policy changes and strategies may be the best solution moving forward. They also identify five criteria for supply chain resilience: reliability, time to innovate, agility, risk exposure, and efficiency. The article argues that localization needs to be considered from a variety of angles and may not look the same across different regions and contexts.

Tickle M and Hannibal C. 2022. **The Use of Technological Innovations in Promoting Effective Humanitarian Aid: A Systematic Review of the Literature.** *International Journal of Technology and Human Interaction*, 18 (1), 1-14. <http://doi.org/10.4018/IJTHI.293204>

This article examines how technological innovations, specifically in information and communication technology (ICT), can be applied to humanitarian supply chains during relief efforts following a disaster. Some possible benefits from using ICT in humanitarian supply chains include reduced costs, improved coordination, increased donor awareness, and increased agility. The study also found that ICT improved data collection and storage, increasing visibility and transparency. These tools also allowed organizations to share information with other organizations, increasing awareness of issues in the supply chain. Although the authors found several benefits to using ICT, there are also barriers, including incompatibility between different systems, volume of data, lack of familiarity with technologies, lack of funding, and security concerns. The article suggests several innovative uses of ICT that could offer the most benefit to humanitarian supply chains: tracking goods and services, a database containing information on past disaster relief efforts, satellite technology to enable internet access in remote areas, and Web 2.0/social media.

UNICEF. 2022. **Six ways UNICEF is innovating to respond to the pandemic and build stronger health systems.** *UNICEF Office of Innovation*. <https://www.unicef.org/innovation/six-innovative-ways-pandemic-response-health-systems>

This article from UNICEF describes six ways the organization has used innovative solutions to address issues caused by the COVID-19 pandemic. The first is the development of a rapidly deployable health emergency facility that can provide screening, isolation, and care during future disease outbreaks. The second is the Real-Time Vaccination Monitoring and Analysis (RT-VaMA) app that can be used to track the usage, coverage, and waste of vaccines. The third is Vaccine MicroArray Patches (VMAPs), a prototype patch device that is adhered to the skin and delivers vaccines through microneedles, eliminating the need for traditional syringes and removing the risks of needle waste and disposal. The fourth is UNICEF's use of data, including the platform MagicBox, to understand the needs of vulnerable populations and monitor the spread of the pandemic. The fifth is UNICEF's involvement in several projects that strengthen oxygen systems around the world. The final innovation is UNICEF's commitment to supporting future innovations by putting out a call for applications through the UNICEF Venture Fund for startups that are using AI, machine learning, or data science technologies to address health needs.

USAID Global Health Supply Chain Program. 2021. **Digitalization of COVID-19 Commodities Supply Management Strengthens Health Delivery in Bangladesh.** <https://www.ghsupplychain.org/news/digitalization-covid-19-commodities-supply-management-strengthens-health-delivery-bangladesh>

This article discusses the development of a comprehensive electronic logistics information management system (eLMIS) for COVID-19 commodities management under USAID's Medicines, Technologies, and Pharmaceutical Services (MTaPS) program in Bangladesh. At the onset of the COVID-19 pandemic, MTaPS developed a basic online system to track the stock of emergency commodities on a daily basis. As the

pandemic progressed and information needs became clearer, MTaPS upgraded the reporting system into an eLMIS that included a quantification tool to display stock availability in real time. This information was critical for making decisions around procurement, distribution, and restocking of COVID commodities. The use of eLMIS demonstrates the importance of a centralized inventory management system to improve decision-making in the field of supply chain management.

Zhang J, Pathak HS, Snowdon A, et al. 2022. **Learning Models for Forecasting Hospital Resource Utilization for COVID-19 Patients in Canada.** *Scientific Reports* 12 (1), 8751. <https://doi.org/10.1038/s41598-022-12491-z>

Researchers in this study developed a machine-learning model that can predict five quantities related to the COVID-19 pandemic: the number of hospital beds, ICU beds, ventilators needed, COVID-19 cases, and COVID-19 deaths. Researchers created a temporal convolutional network (TCN) model and compared it to other models to determine its accuracy. The TCN model's forecasts were consistently more accurate than other models across the entire forecasting period, illustrating its effectiveness as a decision-making tool. The TCN model can examine predictive patterns, meaning that it can look at the relationship between inputs and outputs, which other models cannot. The creators of this model hope to expand its use by inputting other COVID-19-related data to increase the type of information that the tool can predict.



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