Achieving resilient supply chains:
Managing temporary healthcare supply chains during a geopolitical disruption

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Acknowledgement:

This project is funded by the Engineering and Physical Sciences Research Council, grant number EP/T014970/1 and Defence Science & Technology Laboratory (Dstl).

ABSTRACT

Purpose – Geopolitical disruptions significantly impact the management of temporary healthcare supply chains (HSCs). Common across geopolitical disruptions is the interruption to the flow of supplies, calling for organizations to reconfigure their existing supply chains or set up temporary ones. We theoretically and empirically investigate how temporary HSCs are designed to ensure a resilient flow of vital healthcare products during a geopolitical disruption.

Design/methodology/approach – We investigated two different temporary HSCs **–** potable water and blood products **-** that experienced geopolitical disruptions. We purposefully sampled HSCs in deployed medical care where healthcare providers operate in resource austere, politically volatile environments, and timing and access to specialist expertise, medical equipment, and medicines are critical. We built on rich datasets including archival data, 12 expert workshops, and 41 interviews.

Findings – The nature of temporary HSCs (e.g., urgency of demand, time-limited need) and product characteristics (e.g., perishability, strict storage conditions) lead to complexity in designing resilience for temporary HSCs. In contrast to permanent supply chains, temporary HSCs have limited flexibility and redundancy. Collaboration and agility are predominant strategies for enhancing resilience for temporary HSCs.

Originality – This study addresses an under-researched area of investigation by theoretically combining and empirically investigating the supply chain strategies employed by organizations to build up resilience in temporary HSCs.

Practical implications –The study uncovers an urgent need for radical changes in how managers and policymakers responsible for HSC address resilience. During geopolitical disruptions managers and policymakers need to review healthcare regulations across nations and prioritize by activating high levels of information- and knowledge-sharing between nations.

Keywords: *Geopolitical disruptions, healthcare supply chain, supply chain resilience, armed conflicts, temporary supply chain*

1. Introduction

Geopolitical disruptions, defined as risks associated with "the threat, realization, and escalation of adverse events associated with wars, terrorism, and any tensions among states and political actors that affect the peaceful course of international relations" (Caldara and Iacoviello, 2022, p. 1195), have had a significant impact on the management of supply chains across industries (Bednarski *et al.*, 2023; Srai *et al.*, 2023). For example, Houthi rebels' attacks on vessels in the Red Sea forced shipping companies to embark on longer and more expensive reroutes, affecting the availability of electronic products and increasing fuel prices (CNN, 2023). In 2022, Russia invaded Ukraine, triggering sanctions on Russia; organizations reconsidered their relationships with Russian suppliers, and many supply chain managers in Europe had to explore alternative energy sources (Srai *et al.*, 2023). Supply flow interruptions were common across all these geopolitical disruptions and to ensure continuous delivery of critical products organizations looked towards alternative, temporary supply chain reconfigurations (Bednarski *et al.*, 2023; Roscoe *et al.*, 2023).

Temporary healthcare supply chains (HSCs) are particularly important during geopolitical disruptions to ensure the delivery of critical healthcare supplies (Müller *et al.*, 2023). Established over a limited timeframe, they are dismantled once the disruption has been addressed (Müller *et al.*, 2023). Temporary HSCs are mainly concerned with vital products (e.g., vaccines, blood), particularly during major disruptions (Govindan *et al.*, 2020) which must be delivered quickly in order to save lives, many of which are perishable and must be treated with care (e.g., vaccines, immunoglobulins, and antisera are heat and light-sensitive, requiring a cold chain at 2°C - 8°C during transport and storage – MSF, 2024). The unique characteristics of these crucial products, in parallel with the need to secure temporary supply chains in response to a geopolitical disruption, place an onus on developing resilient HSCs (UK MoD, 2022).

We identified two gaps in prior studies which must be addressed. First, supply chain resilience (SCR) - "the ability to withstand a disruption (or a series of disruptions) to maintain the planned performance" (Ivanov, 2022, p. 1414) - in temporary HSCs responding to geopolitical disruptions is an important and timely, yet under-studied, research topic (Cohen and Kouvelis, 2021). Prior studies on geopolitical disruptions have mainly explored the SCR strategies required to ensure resilience in permanent supply chains (Belhadi *et al.*, 2024), including more recently HSCs (Roscoe *et al.*, 2020; Son *et al.*, 2024). For example, Spieske *et al.,* (2022), investigating the procurement of critical medical products during the COVID-19 pandemic, found that long-term collaboration between buyers and suppliers was effective in enabling higher levels of supply security during the pandemic. There is a lack of studies examining temporary HSCs' resilience during geopolitical disruptions (Fernandes and Dube, 2023; Müller *et al.*, 2023), particularly for perishable healthcare products (the setting of our study). Temporary supply chains differ from permanent ones in terms of critical and time-limited need for the product, and urgency of demand (Sarafan *et al.*, 2021; Müller *et al.*, 2023). Furthermore, the perishability of healthcare products creates an additional challenge when managing temporary HSCs (Chen *et al.*, 2022). Thus, further conceptual, and empirical insights are needed to address this vital gap.

Second, the vast majority of SCR studies have focused on individual SCR strategies such as collaboration (Shen and Sun, 2023) and flexibility (Son *et al.*, 2024). While these studies extend our knowledge of strategies to ensure resilience of permanent supply chains, the majority fail to investigate how, in the pursuit of SCR in temporary supply chains, organizations may implement multiple strategies, nor have they looked at the interplay of some or all of these strategies as organizations wrangle with the supply issues foisted by geopolitical disruptions (Cohen *et al.*, 2022; Fernandes and Dube, 2023). This is a crucial, yet underexplored, gap in prior studies as temporary supply chains, particularly those set up in response to geopolitical disruptions, have different characteristics, priorities, and tradeoffs, leading to the adoption of different SCR strategies (Cohen *et al.*, 2022). Focusing on these two gaps, we address the following research question: *How are temporary healthcare supply chains designed to ensure a resilient flow of vital healthcare products during a geopolitical disruption?*

In tackling this question, we investigated two in-depth cases, exploring different temporary HSCs -- (i) potable water; and (ii) blood products -- which were set up in response to two distinct geopolitical disruptions, namely political unrest and an armed conflict. We purposefully sampled temporary HSCs in deployed medical care (i.e., the delivery of critical healthcare services and products in a setting where healthcare providers must mobilize quickly - Phillips *et al.*, 2018). In such a setting, healthcare providers respond swiftly to geopolitical disruptions, establishing temporary HSCs (UN, 2024) to quickly provide critical life-saving products and services (i.e., potable water and blood products in our cases). They usually operate in resource austere, volatile environments, where rapid access to specialist expertise and medical equipment is vital.

This study offers two distinct, yet interrelated, theoretical contributions. First, we explored the challenges confronting healthcare organizations that usually maintain control of their respective temporary HSCs to ensure the delivery of healthcare and life-saving treatments in geopolitical disruptions (Müller *et al.*, 2023; Son *et al.*, 2024). We found that, unlike permanent supply chains (e.g., Ren *et al.*, 2024), temporary HSCs operate in complex resource-constrained environments with limited supplier integration and collaboration between organizations. Despite calls to shorten supply chains (Roscoe *et al.*, 2023), temporary HSCs are often lengthy, originating from the organization's home nation, hindering their flexibility and agility. Additionally, for highly perishable and regulated products such as blood products, redundancy cannot be incorporated into the HSC via stockpiling or alternative suppliers, further impacting the ability to rapidly respond to sudden surges in demand.

Second, we answer the calls by Fernandes and Dube (2023) and Saïah *et al.,* (2023) to provide insights on how healthcare organizations adopted SCR strategies to build up resilience in temporary HSCs. Interestingly, while healthcare organizations concerned with permanent supply chains have paid high attention to flexibility (Dittfeld *et al.*, 2022), we found there was limited adoption in temporary HSCs due to the challenging and volatile environments within which deployed organizations operate. These challenges hampered deployed organization's abilities to resupply, incorporate flexible deliveries, or implement innovative, or novel, approaches. Instead, collaboration was predominantly adopted during geopolitical disruptions via coordination between organizations to ensure alignment of tasks towards the goal of delivering life-saving healthcare and through the sharing of resources and capabilities to improve healthcare provision and create greater resilience across each nation's operations. Prior studies (e.g., Kamalahmadi *et al.*, 2022) mainly considered flexibility and redundancy to enhance SCR. Conversely, we found collaboration (via coordination), and agility are predominant SCR strategies during geopolitical disruptions.

2. Conceptual background

2.1 Geopolitical disruptions and temporary HSCs

Geopolitical disruptions arise from political instability, tensions, and conflict between states and nations (Bednarski *et al.*, 2023; Roscoe *et al.*, 2023) and may occur at an unpredictable scale, simultaneously affecting the whole supply chain (Finkenstadt and Handfield, 2021). For example, in 2016, the UK voted to leave the European Union (EU), which forced many UK companies to relocate European production facilities and UK distribution centers (Moradlou *et al.*, 2021). Managers may view geopolitical disruptions as either problematic, or an opportunity to restructure and improve their existing supply chains (Roscoe *et al.*, 2020). Despite the high impact, complexity and frequency of geopolitical disruptions, theoretical and empirical studies addressing this topic are limited (Bednarski *et al.*, 2023; Moradlou *et al.*, 2021). There is an urgent need for more empirical research into the impact of geopolitical disruptions on supply chains to help organizations survive severe disruptions, and better foresee and reduce impacts (Alexander *et al.*, 2022; Roscoe *et al.*, 2023).

Studies examining geopolitical disruptions on HSCs are scarce (Finkenstadt and Handfield, 2021; Scala and Lindsay, 2021). The healthcare industry is dynamic, with many stakeholders involved in its operations, which may be local, regional, and international and include, for example, volunteers, donors, private organizations, and governments (van Oorschot *et al.*, 2023). Collaboration among different organizations in HSCs plays a vital role in dealing with geopolitical disruptions (Kovács and Sigala, 2021). One commonality in HSCs is the slow adoption of supply chain management practices by the healthcare industry to promote collaboration amongst supply chain partners (Betcheva *et al.*, 2021). Consequently, existing literature has mostly focused on how specific hospitals, rather than a HSC, respond to disruptions (Scala and Lindsay, 2021).

Core HSC objectives are improving quality of life and saving lives (Govindan *et al.*, 2020). For these purposes, HSCs should focus not only on financial but also non-financial measures (e.g., response times; Kovács and Sigala, 2021). For example, Sigala *et al.,* (2022) explored the complexity of an HSC and identified mitigation strategies to reduce delays in delivering personal protective equipment (PPE) during COVID-19. However, these studies only provided a snapshot during the pandemic; there is a need for research investigating other geopolitical disruptions and how HSCs prepare for and respond to these disruptions (Bednarski *et al.*, 2023). Here, exploring geopolitical disruptions such as armed conflict and political unrest - which often play out in challenging and resource-austere environments and are characterized by a significant surge in demand for medical products and healthcare - is critical.

Beyond more permanent HSCs for the delivery of medical consultations (Liu *et al.*, 2023) and medicines (Betcheva *et al.*, 2021), there has been increased interest in temporary HSCs (Sodhi and Tang, 2021; Son *et al.*, 2024) where supply chains are deployed provisionally to provide healthcare products and services to people affected by geopolitical disruptions (Fernandes and Dube, 2023; Müller *et al.*, 2023). Müller *et al.,* (2023) identified three key characteristics that differentiate temporary and permanent HSCs. First, temporary HSCs are built to deliver critical life-saving products that are specific to the demand created by a disruption. For example, during armed conflict, temporary HSCs are adopted in affected areas to meet the surge in demand for blood products, which are essential to saving lives. Second, temporary HSCs are built rapidly by organizations to ease the impact of the disruption on the delivery of critical life-saving products. Third, temporary HSCs are established for a limited time. When there is no longer an urgent and specific need, healthcare organizations can decide to terminate or integrate the temporary HSCs into existing, permanent HSCs.

Recently, several studies have investigated geopolitical disruptions and the role of temporary HSCs (Moradlou *et al.*, 2021; Sigala *et al.*, 2022). For example, following the 2015 Nepal earthquake, Fernandes and Dube (2023) identified strategies employed when building a temporary humanitarian supply chain to provide shelter, which faced limited availability of supplies, unprecedented needs, extensive damage across regions, and a race against time. Müller *et al.* (2023) uncovered dynamic capabilities, an entrepreneurial orientation, and a temporary orientation as enablers of agility for temporary supply chains for PPE during the COVID-19 pandemic. Whilst these studies highlighted that healthcare organizations should prioritize resilience in designing temporary HSCs as it enables organizations to make strategic decisions (e.g., maintaining the supply of critical life-saving products - Scala and Lindsay, 2021), there is a need to systematically investigate SCR. This is important because building SCR is effort-intensive and costly (Müller *et al.*, 2023); organizations need to optimize approaches for building resilience in their temporary HSCs. Also, these studies looked at shelters and PPEs, which have long shelf-lives and do not require strict storage conditions. In contrast, the vast majority of products delivered by temporary HSCs are perishable (Chen *et al.*, 2022), resulting in different challenges for temporary HSCs, calling for consideration of the product characteristics (e.g., perishability) when examining temporary HSCs and SCR (Cohen *et al.*, 2022). Addressing this need, we review SCR literature to identify strategies for designing temporary HSCs.

2.2 Supply chain resilience

Geopolitical disruptions have led many organizations to reconsider their supply chain design (SCD) (Ivanov, 2022; Roscoe *et al.*, 2023). SCD refers to decisions regarding the location and number of manufacturing and warehouse facilities, the capacity of each facility, the product and market each facility should handle, supplier selection and distribution networks (Chopra, 2020). In light of recent geopolitical disruptions, SCR has become a focus of SCD research (e.g., Holgado and Niess, 2023), and a priority for many organizations (e.g., Cohen and Kouvelis, 2021). Geopolitical disruptions have exposed the vulnerability of supply chains, stressing the need for systemic practices to enhance SCR (Alexander *et al.*, 2022) and recent studies investigating SCR are now moving from a focus on an individual organization towards a supply chain perspective to enhance our understanding of SCR and the impact of geopolitical disruptions (Peters *et al.*, 2023).

Improving SCR to better respond to a disruption, however, is often challenging. There are various strategies -- sets of actions organizations can take -- to improve SCR (Cohen *et* *al.*, 2022; Shen and Sun, 2023). Extensive literature reviews on SCR (e.g., Sawyerr and Harrison, 2019; Tukamuhabwa *et al.*, 2015) revealed overlaps and differences between existing SCR strategies and identified the four most cited strategies: (i) flexibility; (ii) redundancy; (iii) collaboration; and (iv) agility. First, flexibility is “an operational ability that assists organizations to efficiently change internally, and/or across their key partners, in response to internal and external uncertainties via effective integration of supply chain relationships” (Fayezi *et al.*, 2017, p. 308). Examples of flexibility include flexible suppliers, flexible deliveries, flexible manufacturing, and production postponement (Ali *et al.*, 2017; Pettit *et al.*, 2013). Second, redundancy “involves the strategic and selective use of spare capacity and inventory that can be invoked during a crisis to cope” (Tukamuhabwa *et al.*, 2015, p. 5604). Organizations can enhance redundancy by improving safety stock, developing backup suppliers, and increasing reverse capacity (Kamalahmadi *et al.*, 2022). Third, collaboration is “a mechanism that combines and deploys external and internal resources across a supply chain to help firms achieve goals that cannot be easily attained alone” (Cai *et al.*, 2016, p. 1247). It includes: (i) cooperation between partners to ensure interests, priorities, and incentives are aligned; and (ii) coordination referring to the effective adjustment and alignment of partners’ tasks to achieve common goals (Roehrich *et al.*, 2020, 2024). Examples of collaboration are information sharing, resource sharing, and incentive alignment (Pettit *et al.*, 2013). Lastly, agility is “a strategic ability that assists organizations to rapidly sense and respond to internal and external uncertainties via effective integration of supply chain relationships” (Fayezi *et al.*, 2017, p. 380). Examples of agility include customizing final products, managing manufacturing processes, and implementing new technologies (Alfalla-Luque *et al.*, 2023). Aligning with recent works on SCR (e.g., Dittfeld *et al.*, 2022; Lusiantoro and Pradiptyo, 2022), we focused on these four strategies in this study.

We identified two important gaps in extant SCR literature. First, studies that examined geopolitical disruptions have primarily adopted individual strategies to enhance SCR for permanent, but not for temporary, supply chains. For example, Stewart and Ivanov (2022), through simulation models, adopted the redundancy strategy and proposed the creation of a new warehouse to enhance SCR in humanitarian operations in a conflict zone in Yemen. Herold *et al.,* (2021) highlighted the importance of flexibility in transport to maintain the flow of healthcare products during the COVID-19 pandemic. More research is needed to explore these SCR strategies for temporary HSCs, which often involve organizations that do not have skills and knowledge of healthcare (Cohen *et al.*, 2022). Sometimes, these organizations are new partners or even competitors (Sodhi and Tang, 2021; Taubeneder *et al.*, 2024). Given that there is no guarantee for future collaboration once temporary HSCs are terminated, each organization within a temporary HSC may have different objectives and levels of trust (Fernandes and Dube, 2023), highlighting the need to enhance understanding of how organizations deal with specific characteristics of temporary HSCs and adopt SCR strategies to build resilience in temporary HSCs (Cohen *et al.*, 2022; Fernandes and Dube, 2023).

Second, there is a need to explore the interactions of SCR strategies and how they enhance (or hinder) SCR (Bednarski *et al.*, 2023; Roscoe *et al.*, 2023). Cohen *et al.* (2022) stressed that there is no universal approach for enhancing the resilience of temporary supply chains. Usually, geopolitical disruptions result in a 'new normal' with greater uncertainties in demand and supply (e.g., product mix) (Alexander *et al.*, 2022). Consequently, organizations need to deploy, concurrently, multiple SCR strategies (Ali *et al.*, 2017; Roscoe *et al.*, 2020) to manage unprecedented disruptions and to adapt to new ways-of-working (Cohen and Kouvelis, 2021; Peters *et al.*, 2023). For example, creating redundancy for perishable products (e.g., blood products) is costly due to short shelf-lives, specific storage conditions, regulations, licensing, and testing burdens. Here, organizations could adopt flexibility strategies (e.g., multiple suppliers) to reduce the investment costs of creating redundancy (Scala and Lindsay, 2021). However, during a geopolitical disruption, moving facilities to localize production is difficult (Roscoe *et al.*, 2023), and solely focusing on flexibility is expensive (Luo and Van Assche, 2023). More studies are needed to explore how to combine flexibility and redundancy to enhance SCR (Ivanov, 2024; Saïah *et al.*, 2023). Alternatively, agility enables managers to sense changes within a supply chain (Alfalla-Luque *et al.*, 2023). However, building agility also requires investment in enhancing flexibility and collaboration (Scala and Lindsay, 2021). There is a need to investigate how the interaction of SCR strategies enhances resilience of temporary HSCs (Dittfeld *et al.*, 2022; Fernandes and Dube, 2023). Focusing on these two gaps is also important for practice and policy as organizations must ensure their SCs withstand a geopolitical disruption (Son *et al.*, 2024).

3. Methods

3.1 Research setting, design, and case selection

We employed a multiple-case design (Yin, 2009) to investigate how temporary HSCs for different healthcare products respond to a geopolitical disruption, and the degree to which they utilize strategies that ensure SCR. We focused on deployed healthcare established and maintained through temporary HSCs where organizations may simultaneously, and/or repeatedly, deploy to many disparate locations and operational scenarios (caused by different geopolitical disruptions). Such a case setting provides rich insights on the challenges of delivering temporary HSCs in response to geopolitical disruptions, and for identifying the strategies for building SCR.

We sampled two distinct geopolitical disruptions, enabling us to explore and contrast the core challenges and enablers for SCR in temporary HSCs: (i) potable water supplied to

British Armed Forces (BAF) operating in Mali during a political coup; and (ii) blood products supplied to a field hospital in a large-scale armed conflict (the War in Afghanistan). These geopolitical disruptions differed substantially in their duration, scale, and objectives. In Mali, insurgent groups fought against the Malian government for independence or greater autonomy for Northern Mali; as part of a UN-led peacekeeping mission, BAF was involved in a small, focused, short-term non-combat mission to support regional stabilization and capability building, providing reconnaissance, logistics, and air support. In contrast, the operation in Afghanistan was a long-term armed conflict (2001-2021), launched in response to the 9/11 attacks in the USA. Here, in a combat role, BAF was part of a large-scale, multinational coalition led by the United States.

The investigated HSCs had several unique qualities that made them logical candidates for theoretical sampling based on the following criteria. First, each temporary HSC was set up in response to a geopolitical disruption (Table 1). Deployed operations are temporary in nature (UN, 2024), and in terms of healthcare, the priority is to secure the swift delivery of life-saving products, rather than the establishment of permanent HSCs. Second, as is characteristic of temporary HSCs, the products were critical, life-saving, and perishable. This is important because it differs in context from permanent supply chains investigated in prior studies focusing on geopolitical disruptions (e.g., Belhadi *et al.*, 2024; Roscoe *et al.*, 2023). Third, we purposefully sampled and compared two distinct temporary HSCs which differed in scale, duration, and objective (Table 1). Fourth, we selected two different products. Although both are life-saving and perishable, they differ in terms of shelf-life and regulatory burden - potable water has a shelf-life of around six months and must meet quality and safety standards whereas most blood products have a very limited shelf-life, ranging from 3.5-35 days, must be refrigerated or frozen, and is subject to strict regulatory oversight. These characteristics have the potential to impact the profile of SCR strategies employed and present an interesting case to explore how organizations deliver these essential products (e.g., the short shelf-life of some healthcare products impacts the ability to use spare capacity and inventory (redundancy) to cope with surges in demand).

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3.2 Data collection and sources

We had a rare opportunity to have extensive access to organizations, managers, and end-users involved in two temporary HSCs set up in response to geopolitical disruptions, and (archival and industry) documents for both, enabling us to fully explore the key concepts under investigation. Our study combined primary (interviews, focus group, workshops) and secondary strategy documents (presentation slides, and government and industry reports) data sources. We collected data using a two-stage strategy. First, during the exploratory research stage (June - October 2021), five pilot interviews (Appendix A) and archival data were collected. Analyzing these data sources helped revise our interview protocol and select appropriate HSCs to investigate the key concepts for our study. Second, the subsequent in-depth research stage (November 2021 - March 2023) involved three researchers conducting 36 interviews (Appendix A) to collect data on each of the investigated HSCs. In parallel, we collected workshop data that enabled us to develop our understanding of current and future HSCs and map each HSC (November 2021 - February 2024). Archival data were collected (Appendix B) to achieve data triangulation (Jick, 1979). Data gathering from multiple sources continued until theoretical saturation was achieved.

Archival and industry data. We collected and analyzed 18 documents, which provided a deeper understanding of the HSC organizations, the sector, the operating environment, healthcare pathways, and regulatory landscape of deployed healthcare.

Interviews. We conducted five pilot interviews with key informants who had a thorough understanding of the HSC, the disruptions, and SCR. We then prepared summaries of the most important points, providing us with an initial understanding of both HSCs. During the in-depth case research stage, 36 interviews were conducted with knowledgeable people (Alvesson, 2003) with different tenure lengths and hierarchical and functional roles across the HSCs. Participants were identified through published directories such as the United Nations Office for the Coordination of Humanitarian Affairs (OHCA) website, and via onward referrals and recommendations. Participant selection criteria combined field experience with professional practice in relevant areas such as field medicine, pharmacy, Water, Sanitation and Hygiene (WASH), operations, logistics and procurement, manufacturing, industry, and academia.

Participants read a participation information sheet and signed a consent form, ahead of an online, face-to-face interview of between 30 and 90 minutes. Discussions were guided by five semi-structured, open-ended questions, designed to elicit the operational requirements for deployed healthcare by asking about the nature of the operational environment, existing capabilities, capability gaps, upstream dependencies, and priority drugs and therapies. An interview protocol was designed which we refined as the research progressed and new insights emerged. The main themes explored were understanding the operational environment; geopolitical disruption; organizational purpose; associated challenges for SCR; temporary HSC capability and resource gaps; characterizing operational requirements; exploring upstream dependencies such as the political backdrop and regulatory influencers; and identifying key healthcare products; delivery of logistics.

Workshops. To assess the performance of the HSCs, we mapped the current HSCs to explore the configuration of the supply chains, where the key issues and challenges lay and how they might be overcome. To achieve this, we conducted twelve workshops (in total 107 participants; over 40 hours) with expertise in one or more key areas, for example: logistics;

operations; healthcare innovation; and clinical practice. Recorded group reviews and discussions enabled us to rigorously interrogate, challenge, and refine the resulting supply chain map for each HSC.

We applied specific criteria and measures to ensure research trustworthiness of our case study findings in line with literature recommendations (e.g., Lincoln and Guba, 1985; Appendix C). All interviews were recorded, transcribed, and reviewed by the respective informants to check for consistency.

3.3 Data analysis

As recommended by Barratt *et al.* (2011) and Miles and Huberman (1994), data coding and analysis activities took place parallel to data collection. Notes from the pilot interviews, as well as archival data collected during the exploratory research stage, were assessed, and discussed by the researchers to uncover key characteristics of geopolitical disruptions, HSCs and SCR, helping our case selection and setting up the subsequent in-depth case research stage. Interview and workshop transcripts, notes, and archival data sources were subsequently coded using the data analysis software NVivo.

Data analysis followed a hybrid approach combining theory and data-driven analysis. Deductive coding enabled the exploration of existing concepts within our novel data sources, whilst inductive coding led to the identification and incorporation of novel insights from our data. Analysis followed two main phases: (i) development of a preliminary, deductive coding framework based on key themes identified from the literature; and (ii) iterative open coding of data sources, identifying and developing inductive themes into the nascent coding framework, combined with ongoing review and refinement to build an understanding of the relationships and interdependencies between themes - axial coding. More specifically, before coding, we identified several provisional themes (i.e., flexibility, redundancy, collaboration, and agility) from prior studies, ensuring a clear link to prior literature, while providing scope to incorporate emerging themes such as ‘interoperability’, ‘goals’, and ‘responsiveness’ (i.e., open coding; Miles and Huberman, 1994).

To assure the quality of the coding process, two researchers discussed the initial open codes and established the initial coding structure, after which one researcher continued coding all transcripts and other documents. To enhance quality of data analysis, two researchers each coded three transcripts from one of the cases. Results between coders were compared to reduce potential biases or blindness to emerging constructs, with differences being resolved by trying to reconcile differing interpretations. Codes that could not be reconciled were critically evaluated by the two researchers for their relevance. Emerging key themes and case insights were extensively discussed with the whole author team, forcing 100% inter-coder reliability (Appendix D).

4. Findings

4.1 Potable water

4.1.1 Healthcare product and nature of the geopolitical disruption

A temporary potable water supply chain was established for Op Newcombe (2020-2022), a small-scale, non-combat British operation providing support to the United Nations Multidimensional Integrated Stabilization Mission in Mali (MINUSMA), which involved peacekeepers from 56 different countries aiding the transitional authorities in stabilizing the country following a period of significant civil and political unrest (MoD, 2020). As with all peacekeeping missions, MINUSMA and Newcombe were temporary operations (UN, 2024); around 300 UK personnel undertook long-range reconnaissance patrols for four to six-weeks duration to help the UN better understand how to support the people of Mali (Table 1). The uneven geographic distribution of water resources and extreme weather (heavy rain storms, extreme drought and sand storms - USAID, 2023), the risk of extremist attacks and theft along Mali's roads made resupply by land extremely challenging (UN, 2024), a characteristic common to many missions, which often take place in perilous locations: *"You have other problems that have to do with stealing equipment, attacks, you know, violence, you know, nothing is safe"* (P9-MED).

Water sanitation and hygiene (WASH) is vital in ensuring the delivery of effective healthcare, and underpinning infection prevention control (IPC) and minimizing disease outbreaks and transition (WHO, 2019, 2020). As is often the case for deployed operations, the existing (permanent) infrastructure for water and sanitation in Mali was poor, prone to disruption and overwhelmed, exacerbating the risk of disease transmission and outbreaks. On a humanitarian and social level, water is a scarce resource in Mali, using local supplies could have fostered tensions between the UN and local communities (UN, 2024) and care was taken to avoid perceptions within the Malian population that foreign forces were placing additional burdens on Mali's water and healthcare systems. Also, with daytime temperatures regularly exceeding 40°C, the establishment of a reliable, temporary HSC of potable water was integral to a range of applications from drinking water to medical care for the replacement of fluids, drug delivery, wound irrigation, and cleaning: "*We need to have our own water that is potable and usable for the staff and the patients, all the way to the secondary care hospital, it needs to have a system in place that is able to produce clean water*" (P11-MED).

A longer-term option would have involved buying bottled water locally, however sources would need to be approved by the UN. A more permanent solution would have been the digging of wells or boreholes, but the water would need to meet strict quality standards and bearing in mind the urgent need for this life-saving healthcare product, would take up too much time: "*A lot of places we will dig a well, but that takes quite a lot of time, […] weeks* *and months*" (P5-INN) and initially, this temporary quick-fix of potable water supplied predominantly by air was deployed.

4.1.2 SCR within HSC

For Op Newcombe there was a strong need to minimize reliance on resupply convoys, resulting in very little flexibility within the HSC. Consequently, six-week supplies were transported from the UK by air and decanted into storage tanks. To further negate resupplies and to allow for variability and surges in demand, redundancy was incorporated in the HSC through contingency stockpiling via large inventories of potable water: *"I think with some of it surely has to be about resilience within the system, because actually the demand is very variable. The demand is something you cannot control. […] So, some value is you're having the capability and the resilience to deliver"* (P57-MED).

As an UN-led operation, with limited healthcare facilities and clinical personnel, partner nations collaborated and combined medical resources and capabilities to enhance healthcare provision and reach higher collective SCR, allowing rapid reactions to any emergencies and surges in demand: *"We will often rely on other partner nations for other services […]. The effort to deploy a few 100 people somewhere is huge. So, it is partnerships are what we work on"* (P28-LOG). To foster collaboration through coordination, a clear chain of command was established amongst the partner nations to prevent duplication of assurance and governance measures: *"If you are working on any ops where the UN are involved, then the UN expect to have their own regulations, which are separate to ours"* (P79-MED).

Collaboration with the host nation, Mali, however, was at times testing and BAF had to navigate local politics and power struggles, further impacting resupply: "*One of the issues was visas, […], the host nation has to impose their ongoing authority when they have* *effectively got this massive organization taking over large parts of the healthcare-insecurity is to flex on things like visa requirements"* (P28-LOG). This lack of collaboration limited the ability of the mission to rapidly respond to sudden surges to demand, thus hindering the ability to deliver a resilient HSC.

Although not burdened with the demands associated with cold chains, potable water must be stored at a cool temperature (10-20 °C) and away from direct sunlight (WHO, 2020) to ensure that the safety and quality of this critical healthcare product were maintained: "[potable water] *would then be stored in some kind of temperature-controlled store within a reasonable temperature range to remain officially usable for appropriate for clinical use*" (P57-MED). The need for temperature-controlled storage was a vulnerability, creating another resource dependency - a need for power: *"There is need for self-sufficient power when deploying, as the local power supply cannot be reliable.*" (P45-ACA).

Another vulnerability created by the need for a temperature-controlled environment was the level of wastage: *"I would say there is at any one time a potential loss of 10% as the nearest estimate, but maybe less than 1% if we were working in a more temperate zone where we would not be experiencing environmental temperatures beyond much beyond the normal range, the tolerable range"* (P57-MED). Additional wastage arose from the decanting of one-liter water bottles into storage tankers - our HSC mapping workshops found that an additional 10% of water was lost during this process, it also involved a vast amount of handling/person-hours due to high tonnage of product that needed to be unloaded, decanted and stored, bringing the total cost to approximately £21.20 per liter over a six-week period of supply.

Increased agility within temporary HSCs would require equipment that could be deployed rapidly, easily maneuvered, modular, and scalable, enabling rapid reaction to sudden surges in demand: "*Where you need a surge response, you need something really rapidly - where supply chain sometimes have issues"* (P11-MED). Looking to the next five years, most of the participants at the workshops and interviewees agreed that, for the military, deployed medical operations will likely be delivered within more mobile operating environments, via small, temporary deployed healthcare facilities, with limited medical personnel and resources.

In summary, there was a strong interplay between redundancy and collaboration, via cooperation and coordination between partner nations in the delivery of deployed healthcare. Although the delivery of potable water presented a substantive logistical burden, these strategies helped incorporate a degree of flexibility to this temporary HSC. Priority deployment of potable water and stockpiling ensured ready access, and reduced reliance on resupply which speaks to agility, but this approach though timely, was expensive and created high waste. With calls for potable water production on demand at the point-of-need, greater agility could be achieved by employing innovative manufacturing technologies that are portable, scalable, flexible, and user-friendly. According to one water biotechnologist, it must be: *"Highly localized, easily mobilized, and adaptable; flexible power supply; parts and circuit resilience - surge proof, overall robustness; failsafe - can still operate when IT fails; self-diagnosing system; situationally agnostic - any environment or climate"* (P109-IND).

4.2 Blood products

4.2.1 Healthcare product and nature of the geopolitical disruption

A temporary blood product supply chain was established during the War in Afghanistan to ensure healthcare delivery for injured personnel or civilians. This large-scale combat operation, a response to the 9/11 terrorist attacks, was initiated by the U.S. led invasion (2001), and subsequently bolstered by the invocation of Article 5, and the establishment of a NATO-led International Security Assistance Force (ISAF). The aim was to dismantle embedded terrorist groups and to establish a more stable, secure government, and the resultant operation was characterised by significant troop deployments from multiple NATO countries, over a 20-year period (Table 1). In this disruption, deep rooted socio- and geopolitical drivers were borne out of regional instability, with political leadership and influence contested both domestically and internationally over many decades. In the the wake of 9/11, international allies united to tackle what was seen as a significant global security threat from terrorism.

Blood products are a life-saving commodity used to manage conditions ranging from anemia, blood disorders such as thalassemia, to cancer. They are essential to mitigate hemorrhage in the event of trauma or severe injury, enable both routine and emergency surgery, and improve the quality of life for recipients (NHSBT, 2024). Transfusion represents a critical intervention in hospital settings, in emergency pre-hospital care, and in deployed healthcare, with eleven blood products cited on the WHO Essential Medicines List (EML). The complex attribute profile of these cold-sensitive products creates challenges to vein-to-vein delivery and global HSCs (WHO, 2022).

These challenges are amplified in deployed healthcare, where it is critical to rapidly mobilize and maintain delivery of life-saving blood products in the face of a geopolitical disruption. During the War in Afghanistan, the leading cause of preventable death amongst BAF and civilian personnel was injury-related hemorrhage, with over 600 (very) serious casualties, and over 2,000 admissions to field hospitals for those wounded in action (House of Commons Library, 2021). Improvements to hemorrhage control contributed to significant advancement in medical practice, and the implementation of the "golden hour" principle, ensured medical treatment within one hour of injury (NATO, 2019). Rapid evacuation to escalating levels of medical resource and care, was achieved with air support, with nearly 7,500 medical air evacuations during the British-led Operation Herrick (2002 - 2014) (House of Commons Library, 2021). Early intervention to control bleeding and the administration of blood products to stabilize patients and enable damage control and corrective surgery were essential to delivering improved patient outcomes, as explained by an emergency medicine specialist: *"Number one is hemorrhage control. […] But the life-saving surgery is the control of hemorrhage, so that is a really big one"* (P4-MED). Delivery of blood products using temporary HSCs is vital not only to deliver life-saving interventions in the field, but for operational success, by maintaining an effective combat force and securing public trust and political support.

4.2.2 SCR within HSC

One way in which SCR is built is through collaboration, drawing on established cooperation to enable capability building and a scaled response to a shared objective, which is hard to deliver for individual organizations: *"We do have some capabilities that are genuinely standalone but as a rule, we tend to go into partnership"* (P28-LOG). The coordination of resources has enabled capability building, particularly important for larger scale disruptions such as the War in Afghanistan, where the cost for any individual nation would be prohibitive (e.g., the UK operations from 2001-2021 cost £27.7 billion - House of Commons Library, 2021). For blood products, the high burden of regulatory compliance to ensure safety, combined with a lack of international standardization across key parameters, notably infection testing and blood grouping, prohibits HSC integration across organizations. Indeed, the workshops, mapping this temporary HSC, revealed that the complex attribute profile for blood products, such as perishability, donor dependence, and temperature sensitivity, has resulted in the development of largely national supply networks to meet in-country healthcare demands (WHO, 2022). This presents a key challenge for BAF and the broader defense sector, in that blood products cannot be sourced locally, but rather must be transported via a long logistics tail, as highlighted by one clinician: *"Getting blood into theatre, transporting* *blood across the world from* [primary manufacturer supplier] *in Birmingham is completely insane […]. It has got limited shelf-life, so we are eating into that every day that it is in transit; you have got to transport it cold"* (P17-MED). With each organization adopting this approach of securing supply from its respective home country, we observed little or no integration of blood products across temporary HSCs. This lack of coordination also contributed to the limited flexibility observed within this HSC and hampers its ability to mitigate disruption to supply.

When mapping the delivery of blood products, further challenges to SCR were evident. The first step in securing supply in an emerging scenario is to establish demand. A central BAF organization is responsible for the procurement, delivery, and Quality Assurance Management of blood products. Together with frontline command, they draw up a blood plan, as one Army logistician explained: *"We will speak the frontline command, or a unit before it deploys, who will have a blood plan […]. We tend to have a back-and-forth conversation about what the capacities are, what the casualty estimate is likely to be and what we can provide, and that gets refined"* (P154-LOG). Coordination through clearly delineated responsibilities and established routes of digital communication ensure demand and the supporting capability required to safely deliver blood products, are aligned. Once established, an order is raised with the primary manufacturer and supplier of blood products for BAF. The relationship between these organizations is underpinned by a statutory requirement for the primary manufacturer to supply BAF. However, whilst this is a cooperative relationship, that there is a sole supplier of these critical products is one of several single points of failure identified. This limited supplier base speaks not only to a lack of redundancy but, as a consequence, a lack of flexibility, limiting SCR. A second example is the supply of insulated transport boxes upon which the passive element of cold chain depends. Tight temperature control is essential to ensure the safety and quality of these perishable products, and transport from the primary manufacturer supplier to deployed Medical Treatment Facilities, is in insulated units with in-box temperature monitoring, as noted by one RAF clinician: *"You have got to be able to prove that it has been below four degrees for its entire transport chain"* (P155-MED). Currently, there is one US-based supplier not just supplying BAF, but more widely across the defense sector, resulting in international competition to secure this critical resource. These examples highlight the lack of redundancy, a risk factor in terms of ability to significantly and rapidly scale a cold chain in a large-scale disruption.

Active cold chain delivery is another source of vulnerability for temporary HSCs. Upon receipt in theatre, blood products are stored in blood banking facilities, however it is challenging to power refrigeration and adjunct air conditioning in what are often remote, low resource settings: *"You would have limited access to power, somewhere so remote that there is no kind of normal power source, or in a country where there might be limited fuel power sources, not existing or have been destroyed"* (P2-MED). This hindered the ability to rapidly bolster (low agility) both power and refrigeration, and was a substantive barrier to the scaling of blood product supply chains: *"One of the major challenges was refrigeration, because it is super-hot out there 40 plus degrees in the daytime"* (P155-MED). Blood product stocks were maintained to deliver a high standard of healthcare to injured personnel: *"We are trying to replicate NHS standards in the military environment"* (P28-LOG). However, given the short shelf-life of blood products and the uncertainty of demand, waste can range between 40% - 96%: *"It is frustrating, but it is also reassuring that if you are not using blood products, and that is for a good reason. You hate to see it go to waste. You* [have it] *there because there is obviously that inherent risk that you may have to use it. It is a waste, which we accept"* (P18-LOG). Issues around scaling cold chain and perishability, means stockpiling was not viable and this compounds the lack of redundancy, with limited supplier flexibility and international competition.

Although there were multiple challenges to the delivery of blood products, a key enabler identified was the use of digital systems for information sharing. Both the primary manufacturer supplier and BAF are bound by strict regulations, and there is a common requirement to track every product unit from donor to recipient, enabling reporting to the regulator and to appropriately action any adverse reactions: *"As part of our assurance process and MHRA license, we have to audit and go through all that documentation to make sure every unit is accounted for"* (P154-LOG). This goal alignment has driven the development of inter-organizational digital product tracking and information sharing: *"From within* [UK] *Defence, we can reach back into* [the primary manufacturer supplier] *systems to find out anything we need about the donor. If* [the primary manufacturer supplier] *need to recall anything for any reason, then we have that traceability"* (P154-LOG). Whilst there was a handover of responsibilities from one blood establishment to the next within this HSC, collaboration through resource and data sharing enabled each organization to meet their regulatory reporting requirements, which would not otherwise have been possible. These mechanisms conferred a degree of agility, allowing for a rapid joint response to safety or quality issues that might arise, such as donor or recipient health issues, or temperature excursions.

In summary, interviews and mapping workshops revealed that SCR is limited in temporary blood product supply chains, due to a lack of redundancy, flexibility, and agility, resulting in challenges in establishing, maintaining, and scaling supply in response to a geopolitical disruption. Whilst BAF has good internal coordination and a cooperative relationship with the primary manufacturer, which contributes to the timely delivery of sufficient blood products to theatre, this temporary HSC remains vulnerable. In particular, the lack of redundancy and flexibility in terms of supply routes for critical items and the ability to stockpile blood products and other key resources, have led to competition between organizations. This, combined with the complex attribute profile and essential nature of blood products, limits the agility of supply chains, resulting in high waste.

4.3 Cross-case analysis

4.3.1 Temporary HSCs and disruption

Although the geopolitical disruptions explored differed in scale, duration, and objectives, regional instability was a unifying socio-political driver. For both HSCs, limited local supplies of water in Mali and, for the War in Afghanistan, tight regulations surrounding the use of blood products meant local sourcing was not feasible. Both products were essential for the delivery of deployed healthcare, to meet (inter-)national standards and laws around the medical care of wounded personnel.

Each temporary HSC was established to quickly secure the supply of essential, life-saving healthcare products in response to a geopolitical disruption where time is of the essence, as highlighted by one emergency medicine clinician: *"Avoidable deaths. They are pretty much the same everywhere and they are all time-related"* (P4-MED). Both HSCs deliver critical products which are integral to the delivery of deployed healthcare. In each HSC, relying on existing infrastructures was impossible; temporary supply chains had to be rapidly established. For potable water, an austere local environment, extreme weather conditions, and land transportation subject to attacks made resupply challenging. As a small-scale mission, Op Newcombe was not intended to be long-term or to drain local resources. Establishing a more permanent HSC would be time and resource-consuming as well as challenging and securing a six-week supply of potable water from the UK was the most secure, least invasive, and fastest approach. In contrast, for temporary blood product HSCs, a lack of cross-border interoperability in relation to regulation (notably safety and quality standards) and traceability, meant local sourcing or HSC integration with established partners was not viable. Furthermore, during a geopolitical disruption, local resources (if any) may be stretched or severely disrupted: *"Another big one in most countries is access to blood, which is most lack national blood banks. How are they delivering blood? How are they safely getting it there, cross matching all of this, is a huge, huge gap, especially in conflict countries, where it is oftentimes the most needed"* (P4-MED).

Perishability and shelf-life are product attributes that impact both temporary HSCs, albeit more substantially for blood products. Approaches to managing the logistical challenges across these temporary HSCs differed, and whilst there was an element of temperature control required for storage of both, the burden for potable water was much lower and the shelf-life much longer, enabling stockpiling, whereas for blood products, regular resupply was essential. A point of difference in the end-use of these products, is that water is required for all personnel, throughout an operation, resulting in a high demand for a product that is expensive, challenging to supply and prone to high wastage. Demand for blood products however is less consistent or predictable, and driven by an ethical and operational commitment to ensure availability in the event of injury. Alongside short shelf-life, this is a major contributing factor to waste in this temporary HSC. Overall, when compared to permanent HSCs, the challenges of rapidly establishing supply in remote, low resource environments resulted in lengthy logistical tails and ultimately, very high wastage.

4.3.2 SCR strategies and their interplay

Within both temporary HSCs there was limited flexibility; the challenging conditions and strict quality and safety standards meant the focus was on establishing safe and secure HSCs. For the potable water HSC, this involved minimizing the reliance on resupply, ruling out flexible deliveries, and avoidance of any burden on the local community and its water and sanitation infrastructure, ruling out the use of alternative means of supply. However, a degree of flexibility was maintained via contingency stockpiling of potable water (redundancy) which could be utilized to enable the HSC to adapt to sudden surges in demand (bolstering agility) whilst simultaneously reducing the need for resupply. In contrast, for blood products, the perishability and short shelf-life did not allow for any redundancy through stockpiling and regular resupply was essential. This was exacerbated by a lack of flexibility, with a very limited number of suppliers for blood products as well as key adjunct items, leading to international competition between established partners. These approaches, taken to ensure a consistent and secure supply of these essential products, came at a cost, with high waste observed for both HSCs, with lengthy supply chains originating from the home nation (UK in our HSCs).

Both HSCs were representative of organizations from multiple nations, who at the higher-order organization level, demonstrated cooperation to align priorities and interests, and the coordination of operational resources and tasks to jointly achieve a common goal. However, when looking at healthcare provision and the establishment of temporary HSCs, collaboration (notably cooperation) was much less evident, and does not appear to be embedded across all operational levels. Specifically, we found that for each HSC, coalition forces would maintain and utilize their own independent HSCs: *"If we were deployed in a, for example, a multinational UN force and we were supplying medical supplies, we would assume that they all come from the UK"* (P29-MED).

For potable water, this was due to the transitory, short-term nature of the operation and the need for self-sufficiency in a volatile, low-resource setting. A similar siloing was observed for blood product HSCs, albeit due to different drivers, namely a need for regulatory compliance and a lack of international standardization across key parameters, preventing supply chain integration. However, goal alignment and shared regulatory compliance responsibilities with the primary manufacturer supplier led to some coordination within the blood products HSC through digitally enabled data sharing.

For both HSCs, the reliance on supply from the organization's home nation, hindered the HSC's agility, and its ability to effectively integrate or leverage from alternative suppliers. Some intra-organizational coordination was also observed, with clearly defined routes of communication within both HSCs. However, for both HSCs, the overall picture for collaboration was somewhat fragmented, with the lack of inter-organizational cooperation having a significant impact and contributing to long logistical tails, limiting agility.

To summarize, we identified substantive challenges to the establishment, maintenance, and scaling of a temporary HSC when responding to a geopolitical disruption. Although every disruption is unique in terms of socio- and geopolitical drivers, environmental conditions, and scale, there are common challenges which can be anticipated, such as limited access to power or water. Although we observed some strategies to manage known challenges, the essential nature of these products and regulatory complexities, for both healthcare and operational success, led to compromises and acceptance of high cost, lengthy supply chains and waste. Collaboration (cooperation and coordination) delivered capability building and enabled scaling of an overall operational response between organizations to meet a common goal, but at the individual HSC's level, a lack of cooperation was evidenced by siloing of logistics, which impacted the flexibility and agility of each HSC. Although redundancy was employed to confer some SCR, for highly perishable products with limited shelf-lives (e.g. blood products), it was not a viable approach.

5. Discussions

5.1 Theoretical contributions

The aim of temporary HSCs is to improve quality of life and to save lives and, for defense, to maintain an effective combat force. However, the increasing frequency of geopolitical disruptions raises several challenges in managing temporary HSCs. This research empirically examined the operations of two temporary HSCs during two disruptions, responding to calls for studies to improve resilience during geopolitical disruptions (Cohen *et al.*, 2022; Sodhi and Tang, 2021) and contributing to extant literature on geopolitical disruptions and SCR (Moradlou *et al.*, 2021; Roscoe *et al.*, 2023).

First, we expanded the knowledge on the impact of geopolitical disruptions on temporary supply chains (e.g., Fernandes and Dube, 2023; Müller *et al.*, 2023). Uniquely, our study focused on temporary HSCs, a critical but underexplored topic in the literature (Son *et al.*, 2024), which need to urgently deliver critical products to an area affected by geopolitical disruption. Our research offers important insights into the design of temporary HSC as these are commonly employed by organizations deployed in response to geopolitical disruptions (UN, 2024). Whilst the impact of geopolitical disruptions on permanent supply chains is dependent upon supply chain structure (e.g., Ren *et al.*, 2024), our findings show that the supply of critical and life-saving products may often be within resource-constrained environments, which can impede efforts to rapidly respond to the urgent need for healthcare products, and involve multiple organizations working together to assess the severity of disruptions. Our data suggests that healthcare organizations facing geopolitical disruptions quickly design temporary HSCs to deliver healthcare products such as blood and water to save lives.

We provide empirical evidence on how unique characteristics of temporary HSCs create challenges to building resilience in temporary HSCs. Healthcare organizations work urgently and collaborate with other organizations to deliver critical healthcare to deployed operations. We reveal that regulatory compliance to ensure product safety and quality, as well as international standardizations, are particular obstacles to collaboration amid geopolitical disruptions. A consensus on regulations and standardizations across organizations could enhance trust and cooperation within collaborative relationships. Additionally, we find product characteristics (e.g., perishability and shelf-life) are testing for temporary HSCs, impacting their ability to incorporate redundancy. There is widespread agreement in the literature that organizations should consider local sources during geopolitical disruptions (Roscoe *et al.*, 2023); local sources could shorten the supply chain and address perishability and temperature sensitivity characteristics. However, critical healthcare products such as blood and water cannot be sourced locally not only due to quality and safety issues, but also to avoid placing additional burdens on the host nations. In geopolitical disruptions, key infrastructures such as water, transport, and power are already struggling to meet in-country demand and placing further demand on these systems could give rise to tensions between HSC organizations and local communities. Consequently, we argue that offshoring the supply of critical products, away from the nation/region affected by the geopolitical disruption, is a characteristic of temporary HSCs.

Second, we empirically investigated how healthcare organizations adopt SCR strategies to build resilience of temporary HSCs. In our sample, deployed healthcare organizations employed, to varying degrees, the four SCR strategies examined with product attributes determining which strategies could be employed. We found that although healthcare organizations pay high attention to the flexibility strategy when building temporary HSCs (Sigala *et al.*, 2022), this is difficult to implement in practice. The volatile environments caused by geopolitical disruptions create challenges for healthcare organizations in accessing supply networks (Müller *et al.*, 2023) and, thus, make it difficult to install flexibility into their deliveries. Therefore, although flexibility is an important SCR strategy for temporary HSCs, product characteristics (e.g., short shelf-life; storage conditions) and volatile, challenging environments lead to limited flexibility in temporary HSCs. In an attempt to implement some flexibility into temporary HSCs, for less perishable products, healthcare organizations adopt redundancy strategies (e.g., redundancy in inventory) to deal with any sudden surges in demand. Dittfeld *et al.,* (2022) found that perishability is not important in ensuring resilience in permanent supply chains. However, we found that, in temporary HSCs, the adoption of redundancy strategy is an unviable option for highly perishable products (e.g., blood) where short shelf-lives, and the reliance on refrigeration units makes stockpiling of these products costly and difficult due to power constraints.

Our findings also highlighted the problems that can occur when a collaboration strategy is not fully embedded at all tiers of a temporary HSC. Collaboration enhances information, capability, and resource sharing amongst organizations in temporary HSCs, and given that these elements are critical for temporary HSCs, lead healthcare organizations (manufacturers) paid high attention to adopting coordination strategies in the face of disruptions, however, this may not permeate across all tiers within temporary supply chains. This is because geopolitical disruptions negatively affect the information flow within a supply chain, and low-tier organizations may not have access to information or the information they receive is scarce (Cohen *et al.*, 2022; Phillips *et al.*, 2023). Consequently, during geopolitical disruptions, low-tier organizations' managers make decisions based on incomplete information (Moradlou *et al.*, 2021), and this challenges coordination within temporary supply chains. In permanent supply chains, low-tier organizations extensively use digital systems (Belhadi *et al.*, 2024). Interestingly, we found that for temporary HSCs, lead healthcare organizations use digital systems to enhance communication between organizations for rapid decision-making and coordination amid a disruption, but that this is more relevant to highly regulated products such as blood which have complex product attributes and, legally, must share full information along the HSC. Additionally, we found limited cooperation in temporary HSCs. Most organizations in temporary HSCs have developed their own ways-of-working and are under time-pressure to deliver critical saving-live products. In line with (Roehrich *et al.*, 2023, 2024), we claim that these factors limit the adoption of cooperation practices between organizations in temporary HSCs.

The literature highlighted the need to consider multiple SCR strategies concurrently (Roscoe *et al.*, 2020) but provided little detail on how these strategies may interact and enhance resilience (Fernandes and Dube, 2023; Saïah *et al.*, 2023). Therefore, our research sought to address this gap by providing empirical evidence on how the interaction between SCR strategies enhances resilience of temporary HSCs during geopolitical disruptions. The interaction between flexibility and redundancy strategies has been regarded as a main approach to enhancing SCR (e.g., Kamalahmadi *et al.*, 2022). However, we challenge this view by revealing that specific characteristics of temporary HSCs (e.g., urgent demand, perishable products) enhance the challenges of supply chains during a geopolitical disruption, resulting in the limited adoption of flexibility and redundancy in temporary HSCs.

We also showed that temporary HSCs must cooperate and build up agility to enhance SCR as cooperation and agility enable the sharing of information and knowledge on the nature and intensity of a disruption, which aids rapid decision-making. Embedding cooperation throughout the HSC is more important when products are constrained by cold chains -- resource and data sharing providing some agility, enabling a rapid joint response to major issues such as safety or quality issues, temperature excursions, and fluctuations in demand. This insight is supported by calls for investigating the deployment of SCR strategies reflecting specific characteristics of supply chains and products (Chen *et al.*, 2022; Cohen *et al.*, 2022).

Merely focusing on agility could limit the ability of an organization to respond to future disruptions (Cohen and Kouvelis, 2021), particularly in the "never normal" world. We support the call for the adoption of new technologies by temporary HSCs (Kovács and Sigala, 2021) and highlight the interplay between agility and collaboration. For example, HSCs are under pressure to adopt technologies (e.g., 3D printing, drones) to deliver medical equipment quickly (Phillips *et al.*, 2022, 2023) and enhance information- and resource-sharing in the face of disruptions (van Oorschot *et al.*, 2023). (Healthcare) producers may seek to implement the agility strategy through using new production technology (e.g., portable water production), and coordinating with other organizations to improve production processes.

Building on our findings, we advanced an empirically informed matrix (Figure 1) to illustrate the strategies used to build up resilience in temporary supply chains in the face of geopolitical disruptions. Our research has distilled two overarching factors impacting on the strategies used to build up resilience for temporary supply chains in the face of geopolitical disruptions. These are "operating environment" and "product perishability." Operating environment represents the environment in which temporary supply chains function, ranging from "near normal" (e.g., often seen in conventional settings) to "extreme/austere" (e.g., often seen in geopolitical disruptions). Product perishability relates to the shelf-lives of products, ranging from "low" (e.g., products can be stored for a long time and in any condition) to "high" (e.g., products have very short shelf-lives). Our literature review showed that organizations could adopt flexibility, redundancy, collaboration, and agility strategies individually to enhance resilience under near normal environments (e.g., Sawyerr and Harrison, 2019; Tukamuhabwa *et al.*, 2015). We focused on geopolitical disruptions, which are often played out in extreme/austere environments, and empirically evidenced the need to adopt multiple strategies for developing resilience in supply chains during geopolitical disruptions. Where products are highly perishable, organizations may focus on implementing the agility strategy to enhance the sharing of information, knowledge and resources among supply chain partners, supporting cooperation to align priorities and objectives within supply chains. Also, the interplay between agility and cooperation increases coordination as supply chain partners can have more timely and accurate information, supporting the decision-making process and achievement of common goals. Where products are not perishable, organizations may focus on redundancy strategy (e.g., stockpiling) as this enables flexibility within organizations (e.g., respond to sudden surges or fluctuations in demand).

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5.2 Limitations and further research directions

Despite the contributions above, our study has limitations leading to potential future research directions. First, we only examined supply chains of critical life-saving products with perishability and strict storage conditions. Future research could explore other supply chains (which deliver different types of products and/or services and may have different requirements) to investigate how organizations balance and adopt multiple SCR strategies. For instance, other supply chains (e.g., automotive) and types of geopolitical disruptions (e.g., trade wars), resulting in different characteristics of products, demand, and power asymmetries, could be considered to further examine the deployment of temporary supply chains.

Given the urgent need for healthcare products during geopolitical disruptions, this research did not consider performance measures of temporary HSCs. While we focused on the speed of temporary HSCs, other common measures of supply chains (e.g., costs, quality, and safety) (Müller *et al.*, 2023) could be considered in future studies. For instance, examining how temporary HSCs, experiencing limited resources, balance speed of response against these other measures when adopting SCR strategies.

Finally, this study leveraged many data sources, including interviews, workshops, and archival data. Future studies may use behavioral experiments to uncover the role that individual managers and policymakers play in shaping the structure, agility, and resilience of supply chains to deliver vital products and/or services during disruptions. For example, future research could explore who, at what (hierarchical) level, and job role (e.g., operations manager, director, politician) makes decisions regarding supply chain design, thus influencing SCR.

5.3 Managerial and policy implications

Our findings show that temporary HSCs already play an integral role in the delivery of critical products to areas experiencing geopolitical disruptions. However, although we have seen that key SCR strategies have been implemented and a degree of interplay between these strategies, notably flexibility, redundancy, and collaboration (via cooperation and coordination), we still found evidence that organizations rely on lengthy supply chains constrained by heavy logistical burdens and limited collaboration between organizations due to the use of different regulatory frameworks and standards. Fostering closer collaboration may give rise to issues such as how quality and safety will be controlled across organizations, consequently, it may be worthwhile for public organizations and policymakers to review healthcare regulations across nations, to capture and understand the potential implications of the variances in frameworks in terms of the ability to deliver life-saving healthcare.

In fostering flexibility, we found organizations would employ redundancy as a strategy, using contingency stockpiling to respond to significant fluctuations in demand. Moving to the future, those delivering healthcare products may need to consider the resilience benefits of introducing innovative production technologies that can bring manufacturing closer to the point-of-need to mitigate the uncertainty and reliance on lengthy and exposed supply chains.

As this study has highlighted, the capability to deliver vital healthcare products in the field is a clinical priority, and strengthening SCR (across all four strategies) could improve patient outcomes. Thus, geopolitical disruptions require radical changes in how temporary HSC managers and policymakers think about employing SCR strategies in the "never normal" world. Temporary HSCs will need to adapt to deliver critical healthcare supplies and therapies on-demand, and in the required quantity and quality, close to the point of need thus minimizing the dependency on lengthy logistical tails.

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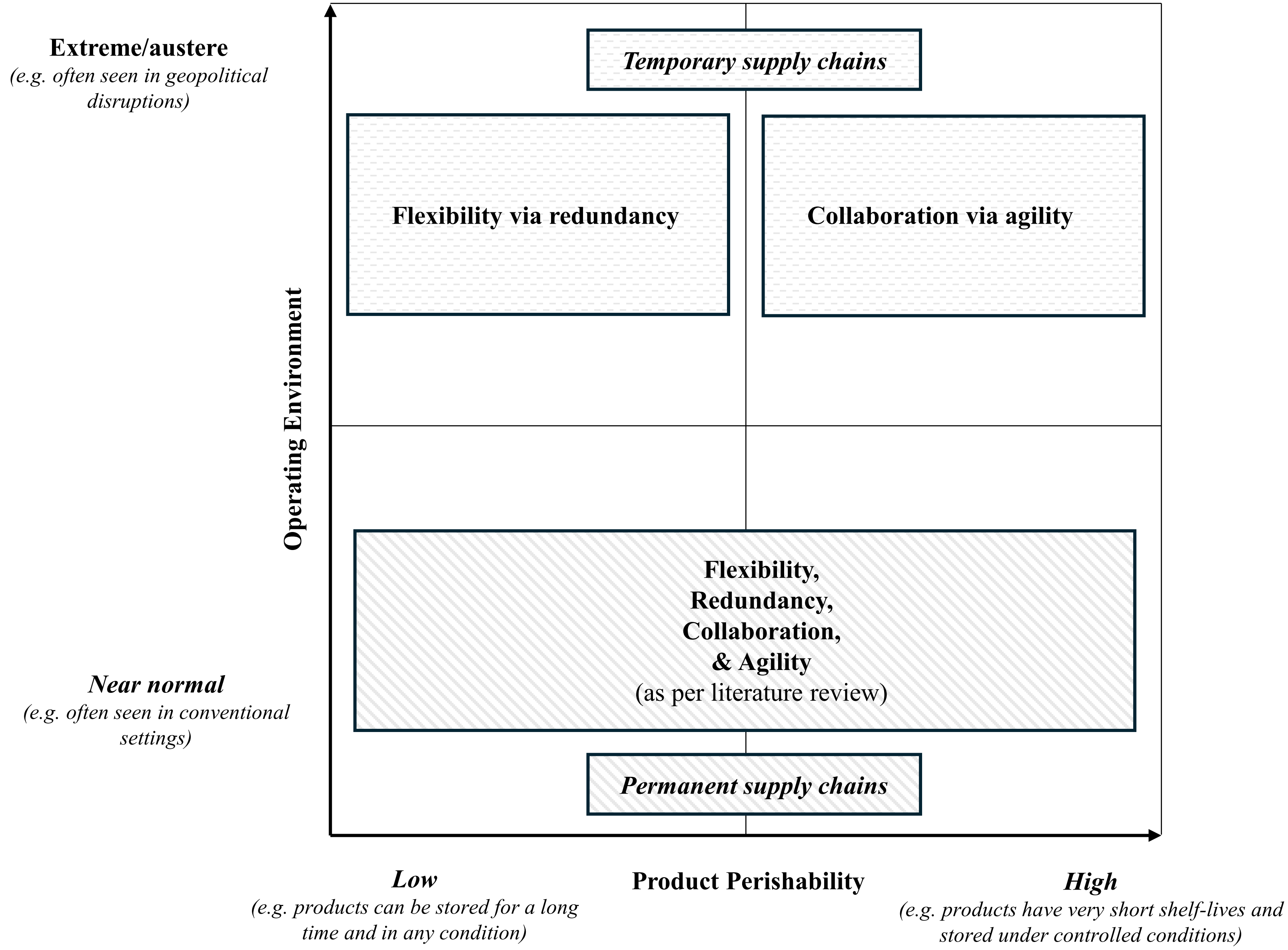
Table 1 Overview of investigated HSCs

Temporary HSCs	Disruption *(investigated)* & operating environment	Supply context	Lifesaving	Perishable	Healthcare supply chain (HSC) characteristics
Potable water A reliable supply of potable water is integral to a range of applications from drinking water to medical care for the replacement of fluids, drug delivery, wound irrigation, and cleaning, particularly far forward in the patient care pathway. Water sanitation and hygiene (WASH) is vital in the delivery of effective healthcare and underpins infection prevention control (IPC), minimizing disease outbreaks and transition: *"I think it is fair to say that, potentially the most critical is water and sanitation, because without that, nothing else works"* (P1-INN).	A political coup in Mali triggered deployment of an UN-led stabilization mission MINUSMA (Multidimensional Integrated Stabilization Mission in Mali), to support transitional authorities of Mali. Operation Newcome (the BAF component) deployed ≈ 300 military personnel for four to six weeks duration under demanding conditions with daytime temperatures averaging 40°C: *"The access and political situation, the environmental situation, the environment's very challenging, often it might be very hot, dry, or arid. [...] there could be issues of access in terms of transport, so lots of challenges, limited access to resources to function"* (P5-INN).	The first six-week supply of potable water to a field hospital with limited water resources. ≈ 7 tons of water per day was required to support a medical facility of up to 120 staff and patients at a Forward Operating Base. Bottled water (in 1-liter bottles) transported by air and land from a warehouse and decanted into storage tanks at the field hospital, supplying (or resupplying) for up to 42 days.	✓	✓	**Transport and storage** • **Lengthy and complex logistical tail** - covering long distances • **Large logistical load** - water is heavy and bulky to transport • **Large inventory** - stockpiling to manage surges in demand • **High levels of loss** - loss during decanting and disposal of 1000s of bottles used to transport water **Perishability** • **Resource intensive** - personnel must monitor shelf-life, water quality plus carry, decant, and remove plastic waste **Regulation** • **Low burden** - shelf-life regulations relate to quality, rather than safety
Blood products Key blood products - Red Blood Cells (RBCs) and Fresh Frozen Plasma (FFP) - are essential to manage hemorrhage and enable surgical procedures in the field. Injury related hemorrhage is the leading cause of preventable death on BAF deployed operations, and supply of blood products to field hospitals is critical for effective healthcare delivery and patient outcomes: *"Avoidable deaths, they're pretty much the same everywhere and they're all time related. Number one is haemorrhage control, is a big one. And that's not just from gunshot wounds, from any wound. These are big because it's an avoidable death"* (P4-MED).	A large-scale conflict as typified by the War in Afghanistan (2001-2021), where the leading cause of preventable death was injury related haemorrhage. At the hight of the Afghanistan conflict, the UN-authorised NATO led International Security Assistance Force (ISAF) had ~ 132,000 personnel on deployment, from across 50 NATO partner nations (Dempsey, 2021). The field hospital Camp Bastion was established in challenging desert conditions: *"The hallmarks of all of these places are they tend to be pretty austere from an environmental point of view either very cold or very hot. They tend to be challenging on personnel and equipment, be that due to sort of humidity, heat, wind, the sun…the temperature was up to almost 50 degrees in the day, and you can do very little in that sort of temperature"* (P28-LOG).	Supply and resupply of blood products (RBCs and FFP) to military field hospitals with surgical capability, where local supply is of very limited capacity.	✓	✓	**Transport and storage** • **Long logistics tail -** via the home nation civilian blood service • **Transport** - maintenance of cold chain is essential for key blood products, vulnerable to disruption • **Regular resupply -** due to short shelf-life, regular resupply is required **Perishability** **Waste -** high waste at 40 – 96% due to short shelf-life and uncertain demand **Regulation** • **Traceability** - regulatory requirement for 'vein-to-vein' tracking of every unit, to ensure safety and regulatory compliance • **Quality Assurance -** monitoring of transit temperature to ensure safety and efficacy, and regulatory compliance • **Donor dependency -** high testing burden for compatibility and disease screening, and regulatory compliance

Source: Authors' own creation



Source: Authors' own creation

Figure 1 Supply chain resilience strategies for the supply of critical products during geopolitical disruptions

APPENDICES

Appendix A: List of interviewees

Appendix B: Description of policy and industry reports reviewed by the study (secondary data)

Appendix C: Summary of research credibility

Appendix D: Excerpt from coding schema

Appendix A: List of interviewees

#	ID	Sector	Role	Duration *(in mins)*
Pilot-1	P1-INN	Humanitarian	Innovation	37
Pilot-2	P2-MED	Humanitarian	Medical	34
Pilot-3	P3-MED	Emergency/NHS	Medical	62
Pilot-4	P4-MED	Humanitarian	Medical	32
Pilot-5	P5-INN	Military	Innovation	31
1	P1-INN	Humanitarian	Innovation	49
2	P2-MED	Humanitarian	Medical	31
3	P3-MED	Emergency/NHS	Medical	69
4	P3-MED	Emergency/NHS	Medical	45
5	P4-MED	Humanitarian	Medical	45
6	P5-INN	Military	Innovation	30
7	P6-MED	Humanitarian	Medical	68
8	P7-OPS	Humanitarian	Operations	40
9	P7-OPS	Humanitarian	Operations	65
10	P8-OPS	Emergency/NHS	Operations	74
11	P9-WAS	Humanitarian	WASH	75
12	P10-LOG	Humanitarian	Logistics	63
13	P11-MED	Humanitarian	Medical	41
14	P11-MED	Humanitarian	Medical	73
15	P12-PHA	Humanitarian	Pharmacy	45
16	P13-LOG	Humanitarian	Logistics	30
17	P14-OPS	Humanitarian	Operations	74
18	P15-INN	Humanitarian	Innovation	44
19	P15-INN	Humanitarian	Innovation	62
20	P16-LOG	Humanitarian	Logistics	54
21	P17-MED	Military	Medical	69
22	P18-LOG	Military	Logistics	38
23	P19-LOG	Emergency/NHS	Logistics	25
24	P20-IND	Industry	Sales	58
25	P21-IND	Industry	Sales	58
26	P22-OPS	Humanitarian	Operations	82
27	P23-LOG	Humanitarian	Logistics	18
28	P24-OPS	Humanitarian	Operations	26
29	P25-RES	Emergency/NHS	Research	69
30	P26-MED	Emergency/NHS	Medical	74
31	P27-RES	Emergency/NHS	Research	30
32	P28-LOG	Military	Procurement	58
33	P29-MED	Military	Medical	46
34	P30-RES	Academia	Research	45
35	P31-RES	Academia	Research	58
36	P32-MED	NHS	Medical	45

Source: Authors' own creation

Appendix B: Description of policy and industry reports (secondary data)

Reference	Brief description	Purpose
Foresight U.K., 2013	Summary Report - The future of manufacturing: a new era of opportunity and challenge for the UK	Develop an understanding of future developments in healthcare manufacturing and supply
Life Sciences Industrial Strategy, 2017	A report to the Government from Office for Life Sciences, HM Government	
Life Sciences Sector Deal, 2017	Presents the need within the UK for new advanced manufacturing capabilities and advances in technology in science and engineering,	
World Economic Forum, 2017	Report calling for manufacturers to augment conventional manufacturing techniques to become sustainable flexible decentralised, resilient and localised	
NHS Supply Chain, 2018	Presents the NHS new operating model to address frequently asked questions	
National Health Service, 2019	Presents the NHS Long Term Plan – a shift from the current mass production approach of patient handling towards a system of care that promotes customised and personalised patient therapy in the NHS	
World Economic Forum, 2024	Global Risks Report	Understanding of geopolitical events and the associated risks
North Atlantic Treaty Organization, 2019	AJP-4.10 Allied Joint Doctrine for Medical Support. Edition C. Version 1	Background as to the nature of the austere environment in which deployed healthcare providors typically operate. e.g., international parterships, operational scale, casualty numbers
United Nations Office for the Coordination of Humanitarian Affairs, 2023	Global Humanitarian Overview, 2023	
Ministry of Defence, 2013	Military Medical Contribution to Health Sector Development within Security and Stabilisation Operations	
Ministry of Defence, 2020	Overview of the deployment of 300 British troops to Mali on UN Peacekeeping Mission	
House of Commons Library, Research Briefing, 2021	Commons briefing on War in Afghanistan statistics: UK deaths, casualties, mission costs and refugees	
World Health Organization, 2019	A worldwide progress report on water, hygiene, and sanitation in healthcare facilities for practical measures to attain universal access	Deeper understanding of the issues related to potable water
World Health Organization, 2020	A worldwide progress report on water, hygiene, and sanitation in healthcare facilities, as first fundamentals	
Joint United Kingdom Blood Transfusion and Tissue Transplantation Services Professional Advisory Committee, 2024	Guidelines for the Blood Transfusion Services in the United Kingdom	To provide background on blood products, their manufacture and use e.g., product profile, storage requirements, shelf life, end use healthcare applications, future trends
NHS Blood and Transplant, 2022	NHSBT Portfolio of Blood Components and Guidance for their Clinical Use	
NHS Blood and Transplant, 2022	Five-year Blood Service Strategy	
World Health Organization, 2022	Global Status Report on Blood Safety and Availability	

Source: Authors' own creation

Appendix C: Summary of research trustworthiness

This table summarizes the different criteria and activities within our study to enhance trustworthiness (adapted from Lincoln and Guba, 1985).

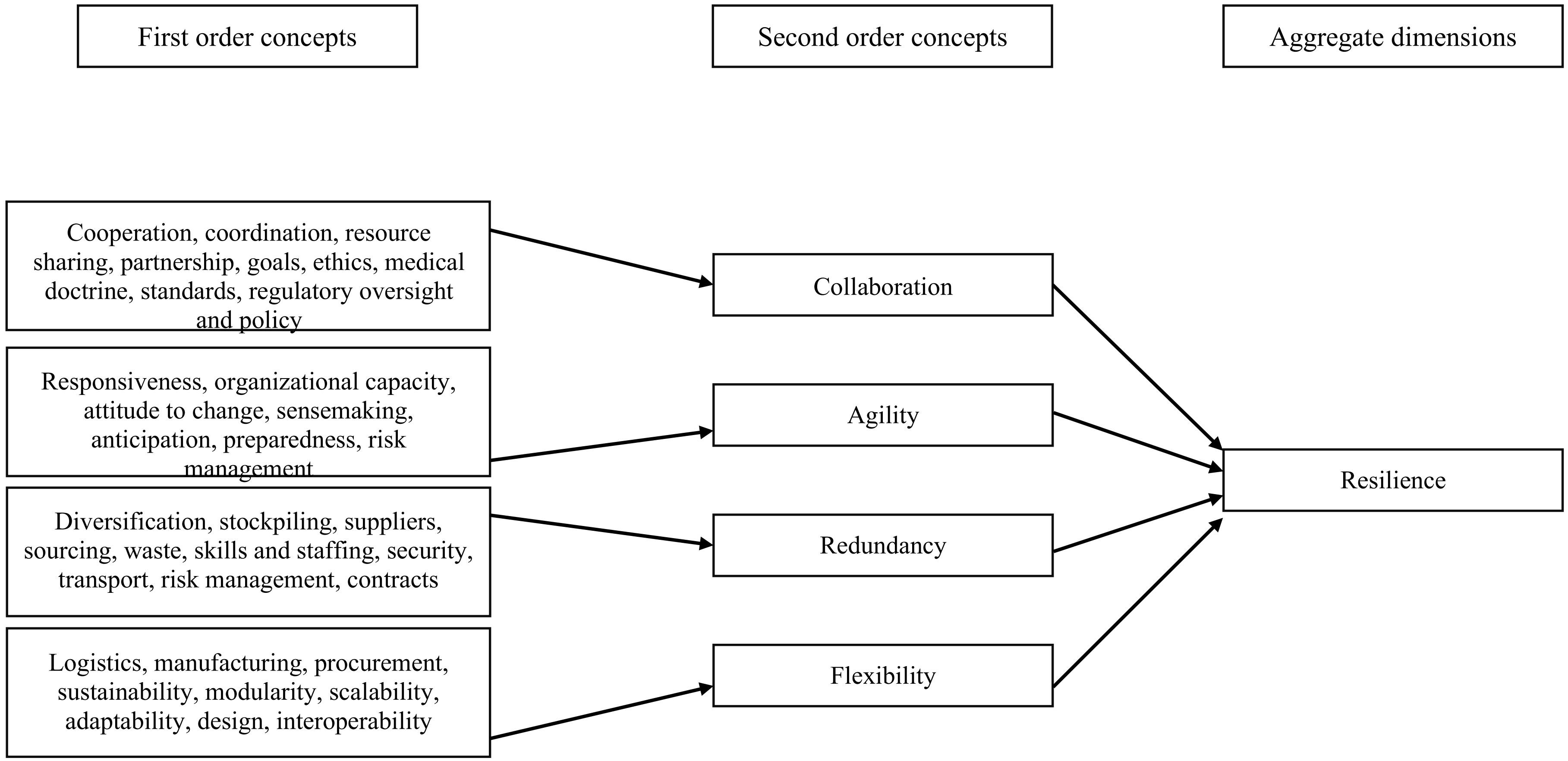
Research trustworthiness criteria	Method for addressing research credibility in this study
Credibility The extent to which results are a believable representation of the data.	• Evidence collected from multiple groups of informants within healthcare supply chains; • Additional documentary evidence (e.g., firm documents and industry reports) collected to support data triangulation; and • Original material (e.g., interview transcripts and documentary evidence) referenced throughout the paper.
Transferability The extent to which findings from one study in one context can be applied to other contexts.	• Analysis of cases was guided by several main concepts that were derived from existing literature (e.g., HSCs; geopolitical disruption; SCR); • Built on 'analytical generalization' by seeking to identify patterns across the cases; • Detailed case study descriptions were written based on all sources of evidence; • HSC case descriptions were discussed during extensive meetings that included the two lead authors as well as a selection of key informants from investigated firms to clarify interview transcripts and verify our analysis; and • Purposeful sampling was employed to select temporary HSCs.
Dependability The extent to which findings are unique to a specific time and place, and explanations remain stable or consistent.	• Interview protocol was established based on concepts from existing literature, and contained the procedures and questions for data collection; and • We created a case database in NVivo and Windows File Explorer while collecting data including, for instance, interview transcripts, observational notes, and secondary data sources.
Confirmability The extent to which interpretations result from participants and the phenomenon rather than researcher bias.	• Two researchers conducted independent coding and data analysis to enhance confirmability; • We held in-depth discussions with participants in workshops and interviews for data clarification; and • As we discussed emerging key themes and case insights with the whole author team, we ensured inter-coder reliability.

Source: Authors' own creation

Reference

Lincoln, Y.S. and Guba, E.G. (1985), *Naturalistic Inquiry*, SAGE Publications, Newberry Park, CA.

Appendix D: Excerpt from coding schema



Source: Authors' own creation

Brief biographies

Dr Linh Duong is a Senior Lecturer in Operations Management at Bristol Business School, UWE, UK. Prior to his current position, Linh worked at the University of Lincoln, UK and Auckland University of Technology, New Zealand. His current research interests focus on sustainable and resilient supply chain management with focuses on vulnerable contexts such as the agri-food industry and small and medium enterprises (SMEs). His research has been published in Public Management Review, Business Strategy and the Environment, and International Journal of Production Research.

Dr Helen S Sanderson is a Senior Research Fellow in Innovation Management at Bristol Business School, UWE, UK. Her research interests lie in understanding the roles of healthcare innovation and advanced manufacturing in transforming healthcare systems and lead users in the adoption new technologies. Helen has worked closely with the MoD, humanitarian sector and NHS to explore deployed healthcare systems and the role of redistributed manufacturing (RDM) to build more resilient supply chains. Helen has a background in life sciences and worked previously at the University of Bristol, UK and her research has been published in European Molecular Biology Organisation Journal, Current Biology, Cell, Molecular Pharmacology, amongst others.

Professor Wendy Phillips is Professor of Innovation at Bristol Business School, UWE, UK. Wendy has spent over 25 years advancing the disciplines of innovation studies and supply chain management. Prior to her current position, Wendy worked at the ESRC Centre for Innovation and Competition at the University of Manchester, UK and the Centre for Research in Strategic Purchasing and Supply (CRiSPS) at the University of Bath, School of Management, UK. Wendy's research impacts policy and practice in procurement in complex public sector supply networks such as the NHS, the Welsh NHS, MoD and UK Higher Education Institutions (HEIs). Wendy leads a large-scale collaborative network supporting research into redistributed manufacturing (RDM) in healthcare – the Redistributed Manufacturing in Healthcare Network (RiHN). Her research has been published in journals such as California Management Review, International Journal of Operations & Production Management, British Medical Journal, Public Management Review, and Policy & Politics.

Professor Jens Roehrich is a Chair in Supply Chain Innovation at the University of Bath, School of Management, UK. Before joining the University of Bath, Jens worked at Imperial College Business School, Imperial College London, UK. A significant strand of his research agenda explores the governance of long-term relationships between public and private organisations with a special focus on the healthcare sector. His research has been published in journals such as the International Journal of Operations & Production Management, Journal of Operations Management, Production and Operations Management, Journal of Management Studies, Public Management Review, British Journal of Management, Social Science & Medicine, and California Management Review.

Victor Uwalaka is a postdoctoral researcher in the Innovation, Operations Management and Supply (IOMS) Research Group, College of Business and Law, UWE, UK. Victor was recently awarded his doctorate, and his thesis developed the business case for redistributed manufacturing in deployed healthcare operations. Prior to joining UWE, Victor worked in petroleum engineering and international management.