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Supply Chain Resilience during Pandemic Disruption: Evidence from Healthcare

Abstract

Purpose

This paper aims to explore how resilience is evident in healthcare supply chains in the public sector when faced with pandemic disruption and to identify any learnings to inform recovery and future readiness phases.

Design/methodology/approach

An exploratory case study was conducted, consisting of seven semi-structured interviews with public sector supply chain actors in the healthcare PPE supply chain. The data included document analysis.

Findings

Key findings show how specific resilience strategies, such as agility, collaboration, flexibility, and redundancy, contributed to supply chain resilience during the COVID-19 pandemic response. Collaboration is identified as a key mechanism for resilience with public sector networks viewed as facilitating this. Established collaborative relationships with suppliers pre-pandemic did not support increased visibility of tiers within the supply chain.

Originality/value

This is one of the first papers to provide in-depth resilience insights through an example of healthcare supply chains during the COVID-19 pandemic.

Keywords: COVID-19, disruption, healthcare, resilience, public sector
Research Paper

Introduction

COVID-19 has caused major disruptions in global supply chains (SCs) (Ivanov, 2020), especially in healthcare (Govindan *et al.*, 2020; Nasr, 2020). Waves of COVID-19 infections are predicted over the next couple of years, with continued disruptions to global healthcare provision and SCs expected (Leite *et al.*, 2020). Therefore, it is critical to understand resilience in healthcare SCs in responding to pandemic related disruptions.

Toba *et al.* (2008) recognised that the SC process is the essential link in the delivery of healthcare services. SCs are a critical, life-saving factor facilitating the delivery of goods and services to the end user, which in healthcare is the patient (Rakovska and Velinova, 2018). Whereas SC disruption in a commercial environment may cause loss of revenue, in healthcare the stakes are much higher, putting lives at risk (Graves *et al.*, 2009; Getele *et al.*, 2019). Where shortages of equipment have been evident, healthcare supply chains do not have the luxury of time for increased manufacturing output to respond to demand (Livingston *et al.*, 2020). For treatment of COVID-19, ventilators are essential for those who are critically ill and personal protective equipment (PPE) is needed by healthcare professionals to minimise transmission of

infection and risks to their own lives. The term PPE is well known amongst non-healthcare/industry personnel as global print and online headlines have continued to report supply disruptions and shortages globally, given the implications on health and safety (Leite et al., 2020). Recent studies have also highlighted the lengths gone to in order to secure PPE such as sending flights to China to minimise delays in accessing and supplying products (Rowan and Laffey, 2020).

Supply chain resilience (SCRES) has developed as a core element in supply chain risk management (SCRM) literature as a strategy to protect against SC risks and disruptions (Christopher and Peck, 2004; Sheffi and Rice, 2005; Ponomarov and Holcomb, 2009; Bhamra *et al.*, 2011). The disruption caused by a pandemic creates unique SC challenges, which are difficult to protect against (Dasaklis *et al.*, 2012; Govindan *et al.*, 2020; Ivanov, 2020). Pandemics highlight the vulnerabilities of global SCs such as concentration of the PPE manufacturing base in China and unprecedented demand on a global scale (Bradsher, 2020). Although pandemics have been recognised in SC risk literature (Pappis *et al.*, 2009; Dasaklis *et al.*, 2012; Calnan *et al.*, 2017), little attention has been given to how resilience can help to mitigate pandemic disruption (Rubbio *et al.*, 2019), especially in healthcare (Syahrir *et al.*, 2015). Thus, there is scope to explore this during the current COVID-19 pandemic.

Through application of a SCRES lens, we will explore:

RQ1 How is SCRES demonstrated in healthcare SCs when faced with pandemic disruption?

RQ2 What lessons have been learned from the tests on resilience as a result of the COVID-19 pandemic?

Therefore, this paper explores resilience in a healthcare SC, focused on PPE. This research makes a contemporary contribution to literature in assessing phases of resilience and evidencing resilience strategies that are adopted during pandemic disruption. We provide a country level focus, moving beyond hospital SC examples currently viewed in the literature base. This paper is structured as follows: a literature review starts with a brief contextualisation of pandemics as a SC risk. Healthcare SCs are considered, after which there is evaluation of SCRES before the methodology is presented. Case study analysis is provided in the findings section and this is followed by the discussion, managerial implications and conclusions. Three propositions are provided to support further research and practice activities.

Literature Review

Supply chain risk management (SCRM) is an established field of study (Fiksel, 2003; Rice and Caniato, 2003; Christopher and Peck, 2004; Peck, 2005; Sheffi and Rice, 2005; Tang, 2006; Trkman and McCormack, 2009; Aqlan and Lam, 2015). Therefore, a full review of this literature base will not be undertaken here. This section will concentrate on classifying the types of risk relevant for this study.

Pandemics are classified as external risks given their impact on demand and supply risks and environmental risks (Christopher and Peck, 2004). The recent pandemic has seen reports of SCs facing both operational and disruption risks. Operational risks (normally small to medium impact) include common uncertainties such as demand uncertainty, delivery lead times and availability of raw materials (Tang, 2006; Cardoso *et al.*, 2015). Disruption risks include natural disasters, epidemics, accidents such as fires, and intentional attacks such as terrorism (Cardoso *et al.*, 2015; Sreedevi and Saranga, 2017; Donadoni *et al.*, 2019). Disruption risks (high impact) include major crises such as epidemics/pandemics that are not as likely to occur as operational risks but would have a much larger impact on the SC members (Tang, 2006; Cardoso *et al.*, 2015).

A pandemic is “*an outbreak of infectious disease that spreads throughout the world and infects a significant proportion of the human population*” (Huynh *et al.*, 2013, p. 238). The increase in global travel, climate change, and population density have acted as accelerants in the spread of disease and epidemics (Dasaklis *et al.*, 2012) though not on the global scale evident with COVID-19. According to Ivanov (2020, p. 2) epidemic/pandemic outbreaks differentiate themselves from other SC risks due to three unique characteristics: “(1) *long-term disruption existence and its unpredictable scaling*, (2) *simultaneous disruption propagation in the SC (i.e. the ripple effect) and epidemic outbreak propagation in the population (i.e. pandemic propagation)*, and (3) *simultaneous disruptions in supply, demand, and logistics infrastructure.*” Pandemic and epidemic preparedness commonly involves contingency plans put in place collaboratively by government agencies and health institutions, including managing emergency medical stock (Johanis, 2007; Dasaklis *et al.*, 2012).

Literature specific to healthcare SCs during epidemics and pandemics is scarce (Dasaklis *et al.*, 2012; Syahrir *et al.*, 2015; Ivanov, 2020). There has been recognition that the impending threat of an infectious disease such as an epidemic could create a situation in which resources are limited and public health is dependent on vaccines and other medical supplies (Graves *et al.*,

2009; Silva *et al.*, 2012; Syahrir *et al.*, 2015). Logistical operations are critical to managing a disease outbreak and literature does not often address the possibility of workforce shortages, and the effects of quarantine on SCs (Dasaklis *et al.*, 2012; Mohanty and Chakravarty, 2013).

Healthcare Supply Chains

A mix of private and public healthcare is evident globally; however, private hospitals situated in urban areas dominate (Durrani, 2016). The varied healthcare systems globally present their own challenges in terms of managing resources, with public and private sector healthcare providers having diverse strategies for managing SCs (Blandine *et al.*, 2018). One commonality is that all healthcare SCs are distinctive from commercial SCs due to their critical impact on saving lives (Kim and Kwon, 2015), but they differ in their response capability. Comparing developed and middle income/developing country contexts is important as their context influences their capacity to respond to emergencies such as a pandemic. The limitations of the ability to respond in terms of emergency procurement, the mechanisms to secure supplies, and access to funds have been assessed more generally for low income and developing country healthcare systems (Dowling, 2011; Durrani, 2016). During COVID-19, Dai *et al.*, (2020) and Garber *et al.*, (2020) have highlighted the ethics in terms of the purchasing power available to Western countries versus developing/low-middle income countries in securing critical supplies during a pandemic. COVID-19 is not the only instance that access to critical materials or fragmented SCs are evident, as the Ebola outbreak saw similar challenges (Garber *et al.*, 2020).

Studies of both developing and developed countries healthcare SCs have illustrated the volumes procured and inventory management. Rakovska and Velinova (2018, p. 4) note that “*the average hospital uses thousands of different types of supplies and equipment,*” which can amount to 40% of a hospital’s operating budget being dedicated toward purchasing medical supplies (McKone-Sweet *et al.*, 2005; Rakovska and Velinova, 2018). This budget for supplies faces further demands on it, based on clinical preferences for products to be used (McKone-Sweet *et al.*, 2005). Such factors make the purchasing and inventory management of these items extremely important but they can also create large opportunities for cost-savings (McKone-Sweet *et al.*, 2005; Rakovska and Velinova, 2018).

It is worth noting the commonality of procuring through distributors in healthcare SCs. In the US in 2009, nearly 80% of healthcare products, valued at roughly \$320 billion, were purchased through distributors (Kwon and Hong, 2011). The use of distributors makes it harder for organisations to trace the origin of their supplies, which can leave them vulnerable to SC disruptions (Graves *et al.*, 2009; Kwon and Kim, 2018). The lack of SC visibility (Dai *et al.*,

2020), increased globalisation (Graves *et al.*, 2009), and medical supplies coming from outside the country of use (Kwon and Kim, 2018) further increase healthcare SC vulnerabilities. For example, 95% of all surgical masks and 70% of respirators purchased in the US each year are sourced from Mexico and China (Kwon and Kim, 2018).

The concept of resource allocation of healthcare products for when infection rates are so high there are not enough vital resources available has been previously considered (Pappis *et al.*, 2009; Silva *et al.*, 2012; Dangerfield *et al.*, 2019). PPE is vital to controlling the transmission of infection during pandemics (Phin *et al.*, 2008; Patel *et al.*, 2017). PPE includes protective clothing specifically designed to protect the wearer from infection (Patel *et al.*, 2017). Patel *et al.* (2017) and Dai *et al.* (2020) discuss issues with the PPE SC, resulting from most PPE being produced offshore and limited ability to rapidly increase production during a public health emergency. Export restriction or the nationalisation of manufacturing facilities are noted as a possible cause of availability issues during an emergency (Patel *et al.*, 2017). In addition, previous pandemic experience has shown risks of PPE being hoarded, impacting visibility and knowledge of stocks, as was illustrated during the outbreak of SARS, when the public and healthcare staff stockpiled out of fear of SC disruption (Sheffi and Rice, 2005; Day, 2014). However, despite potential hoarding, there is recognition from post-SARS evaluations that suppliers do not want to handle large amounts of inventory when pandemic risk recedes (Dai *et al.*, 2020).

Research continues to acknowledge limitations of SCM practices in healthcare as the industry has been slower to adopt SCM practices in comparison to other sectors due to high fragmentation, inefficiencies, and a lack of integration amongst SC members (McKone-Sweet *et al.*, 2005; Kim and Kwon, 2015; Kwon *et al.*, 2016; Kwon and Kim, 2018; Rakovska and Velinova, 2018). Where the benefits of SCM are exemplified in the healthcare sector, this is often considered at the level of a hospital with public and private sector examples given (Rakovska and Velinova, 2018; Blandine *et al.*, 2018). Dai *et al.* (2020) regard this hospital-level SC as being “*excessive in individual-level optimisation*”, which would reinforce a lack of evidence of system level operation and improvement.

Pandemic responses are studied at a hospital level. Considering the lessons learned from the SARS outbreak, Hashikura and Kizu (2009) recommend hospitals keep, at minimum, a stockpile of PPE that would last them eight weeks. Similarly, Phin *et al.* (2008) conducted a pandemic simulation exercise in a UK hospital following government produced pandemic

influenza infection control guidance, issued in 2005. The authors found that the ‘just-in-time’ supply strategy used by the hospital would be insufficient and unsustainable if a pandemic were to occur, especially for PPE. Results from this study flagged up demand uncertainty for PPE. Simulated surgical mask demand increased to 450 times of normal usage but there were further issues with staff uncertainty over the additional measures and in donning and doffing of PPE (Phin *et al.*, 2008). These results highlight consequences for resilience given the global nature of healthcare procurement and the SCs of products such as PPE. In assessing the COVID response, PPE availability and its management must move beyond a hospital level focus. This includes managing the SCs for these products at a regional level (Livingston *et al.*, 2020) and there is brief discussion provided of a national level response (Rowan and Laffey, 2020) where technology could support greater visibility and resilience.

Supply Chain Resilience (SCRES)

SCRES, like SCRM, became a popular topic in literature in the early 2000s (Fiksel, 2003; Rice and Caniato, 2003; Christopher and Peck, 2004). The definition of SCRES varies in literature and has developed over time (Ponomarov and Holcomb, 2009; Hohenstein *et al.*, 2015; Ali *et al.*, 2017). In one of earlier papers to consider resilience in the SC context, the definition of resilience put forward by Rice and Caniato (2003) inferred only the reaction/response and recovery as phases of resilience (Ali *et al.*, 2017). When resilience is defined in the SC context, there is an added element of the growth phase implied (Christopher and Peck, 2004; Fiksel, 2006; Jüttner and Maklan, 2011; Pettit *et al.*, 2013; Wieland and Wallenburg, 2013). This expands the definition to include moving to a more desirable state instead of restricting it to only returning to the original state (Christopher and Peck, 2004; Peck, 2005; Fiksel, 2006). Authors most commonly refer to at least three phases of resilience: readiness, response, and recovery (Ponomarov and Holcomb, 2009; Wieland and Wallenburg, 2013; Martins de Sá *et al.*, 2019; Scholten *et al.*, 2019).

From the 2010s, four phases of resilience are necessary to provide a complete definition and scope with these being: readiness, response, recovery, and growth (Day, 2014; Hohenstein *et al.*, 2015; Ali *et al.*, 2017; Sawyerr and Harrison, 2019). The definition for SCRES used in this paper is, “*the supply chain’s ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state in order to increase customer service, market share and financial performance*” (Hohenstein *et al.*, 2015, p. 108). This definition supports four phases of

SCRES: readiness, response, recovery, and growth. These phases will be assessed in this research.

There are many papers published looking at ways to measure SCRES both on an enterprise level (Sheffi and Rice, 2005; Datta *et al.*, 2007; Pettit *et al.*, 2013; Wieland and Wallenburg, 2013), and a network level (Chowdhury and Quaddus, 2017), but there is no cohesive agreed upon method (Elleuch *et al.*, 2016; Donadoni *et al.*, 2019). Additionally, authors have found empirical-based studies are lacking on this subject (Bhamra *et al.*, 2011; Elleuch *et al.*, 2016; Ali *et al.*, 2017; Chowdhury and Quaddus, 2017).

Elements of Supply Chain Resilience

Commonly, SCRES is measured using elements, which help build resilient capabilities. In previous research, these are referred to as dimensions, attributes, enablers, and enhancers (Erol *et al.*, 2010; Hohenstein *et al.*, 2015; Ali *et al.*, 2017). This large variance in terminology within the literature is cited to be a cause of fragmentation (Hohenstein *et al.*, 2015; Tukamuhabwa *et al.*, 2015; Ali *et al.*, 2017). Multiple authors have attempted to bring consistency to the terminology by referring to these attributes as elements (Christopher and Peck, 2004; Hohenstein *et al.*, 2015; Ali *et al.*, 2017), with elements recognised as flexibility, velocity, visibility, and collaboration (Jüttner and Maklan, 2011; Scholten and Schilder, 2015).

As SCRES literature progresses, researchers often build upon each other's work, adding or adjusting elements they believe are required. Although collaboration had been previously theorised as having a positive relationship with SCRES (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Pettit *et al.*, 2013), Scholten and Schilder (2015) were the first to empirically test it. In addition to proving that collaboration is an element of resilience, their research adds that long relationships with suppliers increase visibility and velocity, contributing to resilience (Scholten and Schilder, 2015).

Strategies of Building Supply Chain Resilience

Understanding SCRES elements can help managers gauge ways to build resilience within their SCs by linking operational concepts and developing action plans or strategies (Scholten and Schilder, 2015). In reviewing SCRES over the past few years, authors continue to identify similar strategies for improving resilience including flexibility, redundancy, collaboration, and agility (Hohenstein *et al.*, 2015; Tukamuhabwa *et al.*, 2015; Ali *et al.*, 2017). Additionally, increasing visibility is considered a proactive strategy and has been supported by many researchers over time (Jüttner and Maklan, 2011; Brandon-Jones *et al.*, 2014; Hohenstein *et al.*,

2015; Scholten and Schilder, 2015; Vanpoucke and Ellis, 2019). Sometimes visibility is viewed as a part of agility (Christopher and Peck, 2004; Li et al., 2015; Tukamuhabwa et al., 2015). Creating redundancy tends to be costly and, if unused, can result in unnecessary investment, whereas flexibility can be used during non-crisis times as well (Rice and Caniato, 2003; Sheffi and Rice, 2005; Tukamuhabwa *et al.*, 2015). A combination of flexibility and redundancy is ideal in order to balance investment cost (Rice and Caniato, 2003; Datta *et al.*, 2007; Stewart *et al.*, 2009; Tukamuhabwa *et al.*, 2015). Tang (2006) suggests “robust” mitigation strategies that are beneficial to a firm regardless of whether a disruption occurs. Strategies, such as postponement, strategic stock, and a flexible and diverse supply base, are more beneficial as they can also improve a firm’s capability to manage supply and demand during normal circumstances (Tang, 2006; Durach *et al.*, 2015).

SCs should be viewed as part of the critical infrastructure of a community or nation and should be managed by the public-private sectors collaboratively to build resilience (Stewart *et al.*, 2009). Ponomarov and Holcomb (2009) discuss disaster resilient communities and how community learning from past disasters, includes working with government in order to become more sustainable and effective during future disasters. This will be used to build national resilience if applied to critical SCs, such as healthcare (Stewart *et al.*, 2009). Canada was affected by the SARS outbreak (Johanis, 2007), and has worked to increase preparedness since (Silva *et al.*, 2012) by implementing over 80% of recommendations from evaluations on how they handled SARS (Webster, 2020). Their previous experience with epidemics has proven beneficial to placing them in a better position now (Austen, 2020; Webster, 2020). Ambulkar *et al.* (2015) considers this concept as ‘supply chain disruption orientation,’ where a firm is more likely to invest in SCRM and better prepare for future disruptions after previous experience.

Healthcare Supply Chain Resilience

SCRES research has primarily focused on manufacturing SCs but researchers have called for more research, specific to service SCs (Tukamuhabwa *et al.*, 2015; Mandal, 2017; Getele *et al.*, 2019). SCRES research is also lacking in the context of healthcare (Graves *et al.*, 2009; Mandal, 2017; Rubbio *et al.*, 2019). Mandal (2017) explores organisational culture and emphasises the importance of resilience in healthcare SCs as it ensures continuity in the ability to provide uninterrupted services to patients, the lack of which could be fatal. Rubbio *et al.* (2019) look at how healthcare systems can develop resilience capabilities and in what ways digital technologies can be utilised to support this. Rowan and Laffey (2020) reference mobile

and blockchain technologies for planned use during the COVID-19 pandemic, but do not provide evidence as to their effectiveness.

Although previous studies have identified pandemics as a SC risk, the classification as a low probability, high-impact disruptive event means there are limited considerations of resilience strategies. In particular, there is a lack of literature discussing SCRES in the healthcare context and limitations in considering SCRES in the public sector, including public health (Stewart *et al.*, 2009; Pettit *et al.*, 2019). The most commonly cited and tested elements of SCRES are flexibility, redundancy, collaboration, visibility, and agility or responsiveness (Hohenstein *et al.*, 2015; Ali *et al.*, 2017). The most frequently recommended strategies for building SCRES include improving flexibility, developing redundancy, collaborating with SC members, increasing SC visibility, and enhancing SC agility (Hohenstein *et al.*, 2015; Scholten and Schilder, 2015; Tukamuhabwa *et al.*, 2015; Ali *et al.*, 2017). We will explore resilience phases and strategies in a single organisational case study of PPE healthcare supply chains, in the public sector in Scotland.

Methodology

We selected a case study as case studies allow for the collection of data that then apply to similar situations (Ponelis, 2015). This is especially useful in the current pandemic situation as experts anticipate additional “waves” of high infection rates (Bergen, 2020; Gallagher, 2020). The case study organisation, National Services Scotland (NSS), is appropriate because they are in charge of procurement and SCs for NHS Scotland and therefore are critical actors in the COVID-19 pandemic response. This allows for assessment of a country level response, rather than a focus on individual or regional hospital SCs. The centralisation of procurement and SCs in NSS were not just a COVID-19 response but long established, as NSS was created by the National Health Services (Scotland) Act of 1978. NSS’ willingness to participate, experience, and knowledge of healthcare SCs, creates a case worth studying and justifies a single case study (Palinkas *et al.*, 2015).

Purposive sampling was applied to strategically identify the case study organisation and the research participants relevant to the phenomenon being researched (Bryman, 2012). In purposive sampling, Charmaz (2012) discusses the use of this ‘initial’ sampling as a starting point which can involve people, places and projects before moving onto theoretical sampling (Charmaz, 2012). Theoretical sampling impacts the study throughout, not just at the start, as the analysis throughout the data gathering process directly informs further sampling activity (Locke, 2001). The initial focus was on NSS at a firm level and NSS staff working on

PPE supply were targeted as respondents. Interviewees were selected by a staff member of NSS who was aware of the level of involvement each employee had in the response to the disruption. At the beginning of the disruption, NSS employees were quickly reorganised into teams focusing on various PPE products. Category managers who normally managed category groups and contracts such as “non-medical (i.e. food)” or any product which was distributed through the National Distribution Centre, were now charged with focusing on only surgical gowns or masks. Employees who were part of these internal PPE teams were selected for interviews. The uncovering of other relevant actors within the PPE response such other relevant actors outside of NSS, meant turning the focus to provide analysis at an enterprise level. All interviewees, through their role in PPE supply, were able to identify elements of resilience in the NSS response and discuss any lessons learned to date.

These interviewees were selected based on their high level of involvement and support they provided to the newly formed PPE teams within NSS. The interviews took place in July of 2020, during the pandemic, following the initial impact of the disruption. In total, seven interviews were conducted; five with NSS staff, one with a Scottish Government Minister, and one with a representative of a quango¹ that collaborated with NSS. The details of each interview are included in Table I, including the employee’s job title, years in that position, and the reference code used for anonymity purposes.

...Insert Table I About Here...

Due to the expertise of the interviewees and their role in the pandemic response, only a small number of interviews were necessary in order to capture the dynamic qualities of pandemic disruption to healthcare PPE SCs (Crouch and McKenzie, 2006; Saunders and Townsend, 2016). The interview guide (see Appendix 1) was designed to capture broad aspects of the event’s (COVID-19 pandemic) impact before going on to gather data on the four phases of SCRES (readiness, response, growth, and recovery) as per the underpinning definition from Hohenstein *et al.* (2015). Interviews were transcribed after being conducted as interviews and analysis was an iterative process.

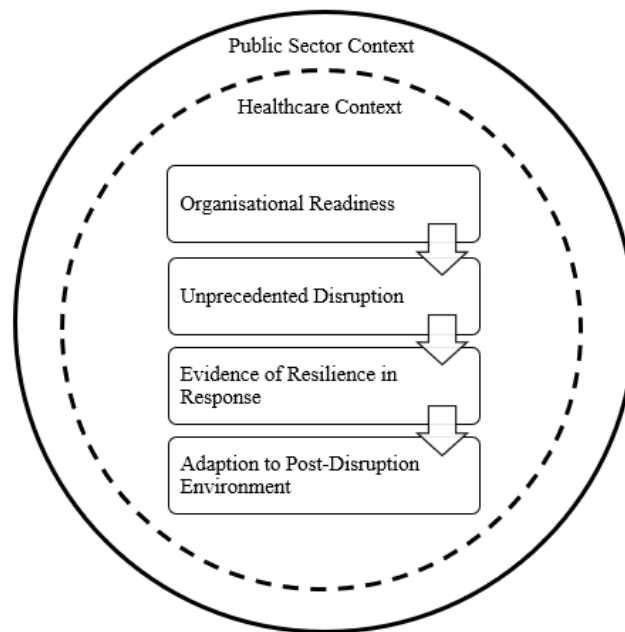
Common in inductive research methods, thematic analysis was used to find and classify themes from the interview transcripts. This allowed us to find broader meanings in the patterns identified akin to the latent approach described by Braun and Clarke (2006). The six phases of

¹A semi-public administrative body outside the civil service but receiving financial support from the government, which makes senior appointments to it. (Oxford University Press, 2020)

thematic analysis put forth by Braun and Clarke (2006), were followed in order to guide the researcher in the analysis process. The first step in thematic analysis was transcription, which was performed in a denaturalised style to focus on the context of the interviews. A denaturalised style maintains the language and speech patterns used by respondents rather than changing or ‘formalising’ their spoken language during the transcription process.

The transcripts were read multiple times and initial thoughts and ideas were recorded. Coding was performed using NVivo and first-order codes were created. Both researchers jointly conducted one interview and the subsequent analysis. Coding was partially theory driven as the goal was to answer the research questions, but the researchers did not allow this to restrict or limit the analysis (Braun and Clarke, 2006). Sub-themes were identified and codes assigned to each sub-theme. Lastly, these sub-themes were stratified into overarching themes. The overarching themes were defined, critiqued, and adjusted to ensure themes were independent and that they accurately represented data (Braun and Clarke, 2006). Through thematic analysis of primary and secondary data, six overarching themes were formulated. The six themes are unprecedented disruption, organisational readiness, evidence of resilience in response, adaptation to post-disruption environment, healthcare context, and public sector context. Each of these themes are presented in the following sub-sections. A thematic map, Figure 1, shows the interrelation of these themes for clarity and Table II shows how the themes were defined, alongside supporting interview data as a coding exemplar. Table III shows themes, subthemes and codes. The case study organisation (on provision of anonymity), provided twenty-five documents at the start of the project, for illustration of current processes. These documents included product specifications for PPE, contract award schedules, and demand models for PPE across Scotland, commodity action reports, and risk and supply updates. These documents aided triangulation, as secondary data were used to corroborate interview data (Saunders, 2016). These were subject to the same thematic analysis as the primary data.

Figure 1: Thematic map from data analysis



...Insert Table II About Here...

...Insert Table III About Here...

Findings

Background

Healthcare provision in Scotland and the wider UK is government funded, free at the point of delivery, and provided by the National Health Service (NHS) or NHS Scotland. Integration of health and social care in Scotland was legislated in 2014. Full structural integration of health and social care is desired but rare, although elements are viewed elsewhere such as New Zealand, Northern Ireland, and Sweden (Pearson and Watson, 2018). For our study, NHS Scotland is an overarching title to situate NSS within its structure. The structure means there are currently 14 regional health boards providing acute (hospital) and community level care such as general practitioner (GP) and dental services across Scotland. Social care is included in community settings but involves not just the NHS, but also the voluntary sector and local authorities, because of integration. Regional or 'territorial' boards and seven other special boards (of which NSS is one) hold the same level status in reporting to Scottish Ministers as

part of the NHS Scotland umbrella. NSS perform procurement for the NHS in Scotland. NSS are a public sector body who deal with 60% of all non-pay spend equivalent to £1.4 billion and engage with over 1,000 suppliers and trade associations (Street, 2019). NSS are the focus of this case study and the structure of NSS and the collaborative linkages (illustrated as broken lines on the graphic) from the COVID-19 pandemic response are shown in Figure 2. NSS are structured in six strategic business units, but the focus in this research is the procurement part of the strategic unit of procurement, commissioning and facilities (NHSNSS.org, 2020). The PPE SC of NSS is the focus of this research as it was one of the most impacted commodity groups within the healthcare setting (Bergen, 2020) during the pandemic.

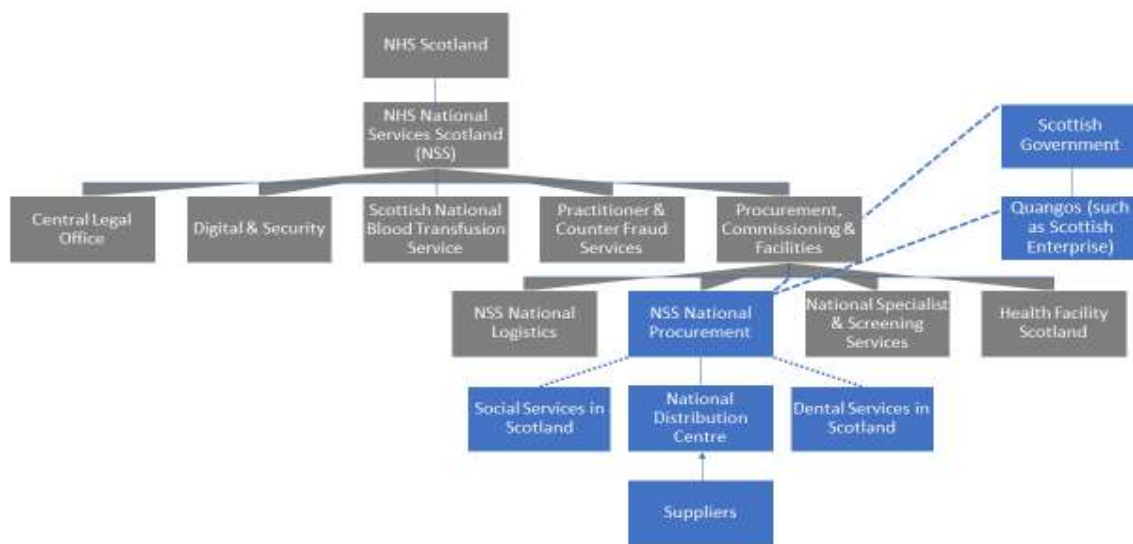


Figure 2: NSS structure with collaboration and supply chain activities shown due to COVID-19

Unprecedented Disruption

Respondents viewed COVID-19 disruption as unprecedented, due to the speed of occurrence and global impact. In addition to this, they have been assessing that the length of impact is increasing and will most likely continue to affect NSS, preventing them from getting back to business as usual. The COVID-19 pandemic simultaneously caused an enormous increase in global demand for PPE and massive supply shortages. Increased demand was perpetuated by fear in the form of panic buying. This was evident publically in retail environments for commodities such as dry goods and toilet paper. According to participants, it also occurred within health boards.

[Panic buying] You'll see it in a health environment as well, particularly because it's disseminated into health boards, so each health board is looking at that saying, "Oh my goodness, have I got enough sanitiser, have I got enough soap?" (CM2).

This type of action fuelled supply shortages, but there were additional variables that emerged in speaking with NSS staff, such as risk of fraud, market profiteering, and export bans, which were enacted by governments to protect their own supply of PPE. This culminated in extremely high levels of market competition and dramatic price increases.

...and everybody else is trying to buy; I mean we went from nine pence for a Type IIR mask up to 90 pence at a point, for the same thing (CM3).

Interestingly, one participant only spoke about raw material shortages. A shortage of melt-blown², a raw material used in face masks, was mentioned in multiple secondary data documents but most participants believed raw material shortages did not impact the overall supply for NSS. Due to NSS operating in a healthcare and public sector context, respondents perceived there to be unique challenges presented because of COVID-19. The criticality of response in some regards was "life or death" yet due-diligence prior to procuring PPE and adherence to procurement regulations was still required.

The procurement principles don't change, even though it's COVID. In the health sector, we have to ensure that the products that we have and the products we procure meet the necessary standards. So that was a challenge (CM2).

In some cases, substitute products were purchased for clinical sites but as these were 'unknown' there were risks as some items, such as face masks, require fit tests for proper protection. As explained by participants, this is important because product consistency will determine staff acceptance.

So because of the unprecedented demand we couldn't get all the products we would normally buy that people were used to. We had to buy products that were different, similar, but different. People accepted them, but that's something you always want to avoid, don't want to have any surprises in a healthcare environment (SM1).

This sentiment appeared in the secondary data discussing the hidden risks in replacement products. During this period, PPE demand was described as a moving target. Everyday product

² A type of non-woven polypropylene fabric

forecasts would be adjusted based on new historical data, but the level of infection was hard to predict, as was behaviour within the health boards.

So, where you might think one member of staff might wear ten masks a day, it just is human nature, they might be wearing a hundred masks a day because they're doubling up and changing them more often. And that's the kind of demand characteristic that you're trying to map out. So quite a challenge (CM3).

The consensus was that no country or company was prepared for such a disruption. Words like 'biblical', 'astronomical' and 'unprecedented' described the level of disruption in the PPE SC.

This was such a global shock, the demand for all this equipment and consumables it was so astronomical that I don't think that anybody, well we know that nobody could cope with that because there was such a big shift. You can't plan for it... (CPI).

Another difficulty commonly mentioned were internal constraints NSS experienced, both in a human resource capacity and in a logistical capacity. Meeting the demand of health boards was critical for frontline worker safety but in doing so, the organisation was stretched to its limits due to extreme pressure on staff.

Organisational Readiness

Through interviews with NSS, it became clear that, prior to the disruption, NSS portrayed multiple aspects of organisational readiness, which, ultimately, helped them respond to the COVID-19 disruption. Key aspects of organisational readiness linked to resilience were evident including collaboration, flexibility, and redundancy.

In terms of organisational readiness, an SCRMM culture was identified as previous resilience tests had been undertaken such as for a flu outbreak and preparing for the Commonwealth Games, held in Glasgow in 2014. This meant there were systems in place, but with COVID-19, nothing had been seen on this scale previously. Despite elements of readiness, discussions reinforced how COVID-19 had highlighted supply chain vulnerabilities. Although many products were made in China or the Far East, understanding of the global SC encompassing distribution hubs in Europe and potential for contamination, meant the organisation undertook a vulnerability analysis as news broke of shutdowns in China.

We started doing vulnerability analysis on all of our suppliers. Couldn't simply focus in China, but understanding that China is just one place and we were anticipating it was going to spread. Our main nervousness believe it or not wasn't so much on the China manufacturing but was about the rest of the supply chain. So, we realised that there were

product made in China in the hubs in Europe, and if the hubs in Europe shut down because all their distribution centres had contamination then the supplies would stop immediately, not in a month or two. So it wasn't just the manufacturing side that concerned us, it was the whole supply chain (SM1).

In addition to vulnerabilities in these extended SCs, the supplier's Lean SC strategy has an impact on NSS.

Many suppliers are Lean in their process because of the commercial pressure - but that commercial pressure and being so Lean means that pipeline, almost, it's very volatile as a consequence (CM2).

These factors exacerbated the disruption on PPE SCs, especially as they are low-cost commodity type items, purchased in bulk from China and the Far East, and commonly have a six-week lead-time. Although NSS as an organisation portrayed many aspects of resilience, it was evident that their assessment of vulnerable SCs lessened their level of preparedness against a large disruption such as COVID-19.

Evidence of Resilience

Previous resilience testing as part of organisational readiness meant that when NSS was affected by COVID-19, typical hallmarks of resilience were evident, in collaboration, flexibility, velocity, and agility. Agility was important in terms of rolling out new (to the organisation) technology to support communication and collaboration with those in the wider public and private sector supply network. There are various IT systems in use across NHS and NSS.

Participants discussed varying aspects, which showed NSS did portray a level of resilience in their response to the SC disruption caused by COVID-19. Most importantly, they continued to meet higher demand despite initial uncertainty as to how this would be achieved. NSS did not simply maintain business continuity; they were also tasked with, and succeeded in, expanding their customer base to include the entire social care sector in Scotland, so not just public sector but also private providers. This feat required them to quadruple their output.

...you need to quadruple your output. You need to do quadruple number of things that you do currently... So, you start that from today. Crikey - OK, how do I do that then? (CM2).

...it was round about March time, I think. And the numbers just got bigger. Massively bigger. Cause we're – NSS we have our own warehouse and logistics setup, but that is only set up for

the hospitals, but the powers that be at Scottish government didn't actually realise that and they just said, "you've got a warehouse, you can do it". It's like well, we can't actually do it, but we did. So we've now got seven more warehouses (CM3).

It was evident that this added to the pressure the organisation was already under and greatly increased the demand of the business. To accomplish this, NSS relied on their existing resources and their staff performed extremely well.

But their performance was just absolutely staggering. These people were commonly working 12 to 16 hour days. And they were doing that for, months. You know, and when I say doing that, I mean seven days a week for months. I don't mean they did that for a week or two. They were just absolutely staggering in the way they did it (PM1).

Participants reminisced that this hard work and dedication occurred while staff were adapting to the new COVID-19 environment, which for most required a completely new way of working. The organisation rolled out Microsoft Teams to facilitate communication, practically overnight, a process that normally would have involved an implementation process of six months, or more.

...this was all against the backdrop in the context of we went from a fully functioning, you know, office environment, office based, to basically having half a dozen people here and everyone else working remotely and trying to adapt to Teams (CM2).

Redundancy

A common aspect of resilience discussed was their method of creating redundancy in the form of a “buy” and “make” strategy. The “buy” piece involved creating buffer stocks, which required purchasing outside of their existing frameworks. The “make” piece was done in collaboration with the Scottish government and quangos, which involved standing up completely new SCs in Scotland.

...one was a kind of 'buy-source' strategy and the other was 'make'. So, if we couldn't buy or source it, could we make it? And that's really, what the focus has been... we've done that through a mixture of initially buying that kit, so getting in the different equipment coming in from mostly from the East but also from standing up new supply chains in Scotland. Certainly, round about surgical gowns, face masks and hand sanitiser. So, all new capabilities are up in Scotland (CP1).

It was clarified that this strategy was made possible because of companies' "willingness to help" as many organisations responded to the "call for action" put out for companies with the capability of making PPE to begin to do so. Although the "make in Scotland" strategy increased, it was perceived to have increased workload for NSS due to the amount of necessary due-diligence. Equally, pursuing this strategy would not have been possible without collaboration with the quango and support from Scottish Government. Additionally, there were various economic benefits of reshoring mentioned by participants, including the potential for export and sustainability opportunities.

Adapting to Post-disruption Environment

There is uncertainty in how things will change in the future and what challenges NSS will face in adapting to a post-COVID-19 environment, given respondents were still in the midst of a pandemic response. The earlier recognition of the efforts of staff and the hours worked in this period has flagged up concerns over the reliance on small groups of key personnel.

It's very reliant upon— in some cases, and within our own business—a very small group of key personnel, and I also think that the business has to recognise that. And every business is the same. It's no different. It's not run by machines; it's not run by robots. It's run by people (CM2).

There is recognition that due to current conditions, there has not been lots of time to consider all implications of what has happened. Many respondents have already identified lessons learned, relating these back to consideration of risk management in the SC. Supplier engagement as part of risk management is viewed as contributing to better SC visibility. This is expected to move beyond tier one suppliers in engagement and assessment of the network.

I think there needs to be a full root and branch of the supplier network and infrastructure and a clearer and better understanding (CM2).

So, I think the risk management of the second tier, sub-tier supply chain, that's what's going to change (SM1).

Reflection was also provided on the new SCs configured as a result of COVID-19. From previous dependence on the supplier base in China and the Far East and now having Scottish based suppliers with capacity, there are opportunities to rebalance the SC. This would contribute to minimising risk.

What this COVID has definitely taught us is that there's probably going have to be a rebalancing of where the supply chain is or not so much is, but how we actually utilise it.

*Should we have a multi-point system, where we have not all the capacity in one country?
(CM1).*

Growth was part of NSS resilience where capacity expanded to supply the social care sector with PPE at the height of the pandemic. There are questions of whether this will continue, given that this sector includes many private companies, or if they can relinquish these responsibilities going forward.

*We're not, still not too sure, who is going to deal with social care and the dentists as we
move forward (CM3).*

Consideration was also paid to improvement of risk reducing measures, such as rotating stock in the pandemic stockpile and ensuring there is enough of the 'right' inventory within it. Previously this was not an NSS/NHS role but given the changes manifesting, there is potential for this to change going forward.

*Previously, we wouldn't, we weren't really in position to do that because the stock was
managed by the Scottish Government. And it was their stock and their budget. Going
forward, we are anticipating it will be a separate budget and a separate team run by NHS to
help manage that (CM3).*

The public sector context of procurement continues to occupy thoughts as almost every participant discussed how using a reshoring strategy as a risk reducing measure, has challenges related to adhering to legislation and adjusting tendering processes to avoid violating state aid competition laws. Going forward and considering the longer-term, it will be important to consider classic SCM trade-offs such as cost vs. security, cost vs. sustainability, and single-supplier vs. multi-supplier sourcing strategies.

*There's obviously been a big challenge in the past about cost differential between, you know,
from a geographic perspective across the Globe and low-cost manufacturing, versus if you
look at here than in essence it is high cost manufacturing... you can't get away from that
(CM2).*

*So in ten years, I'd like to think that we will maintain this focus, kind of maintain this security
and resilience because we don't want this to happen again, but at the same time we also have
to be conscious of the investment of the client to maintain a cost-competitive economy and
supply base (CP1).*

Healthcare Context

All four of the previous themes operate within the context of healthcare. Participants mentioned ways in which procurement for healthcare is unique, such as customer requirements and product diversity. Customer requirements include clinical preferences, safety, and importance of quality. There are varying preferences contingent on the type of product and although standardisation may benefit, there are other challenges in the health arena that can rule this out.

Because if you have multiple suppliers, you have multiple different products. And that's a problem. That's definitely a problem... You have to have a consistent product. So in some areas I think it will drive us to more a standardised approach of a product that people can depend on (SM1).

If Scotland used only one product and that product then in five years' time was faulty, you'd have to re-implant a new heart valve in every single person, whereas if you actually take a different approach which is to have a third of the patients using different products. So there's a whole strategy behind from the clinical side, as to why you probably wouldn't have one product and that has to be understood and in filtered into your supply chain and your procurement decisions (CM1).

The tendering process requires close collaboration with clinical staff in order to ensure they are sourcing adequate goods, resulting in NSS being extremely customer focused. Evidence of this was in the secondary data. NSS is purchasing a large range of items, from extremely complex medical equipment to basic commodities. This range of products requires various strategies and expertise in many different categories. It was clear that the healthcare context has influenced their response to COVID-19 disruption, especially in terms of performing due-diligence, as mentioned previously. During the disruption, health boards had to accept alternate products due to supply constraints and this issue needs considered in long-term resilience planning, going forward.

We could get equipment but it's all slightly different. And for me when you're operating in a highly stressful environment such as an ICU area, the last thing you want is four different ventilators and they all operate different (SM1).

Public Sector Context

It frequently mentioned by participants that NHS Scotland is a public health service, and is paid for via taxation. The fact that they operate within the public sector was a recurring theme throughout the interviews. It was stressed that public sector procurement requires a level of

transparency and adherence to legislation. The importance of cost-savings and legislation requiring the award of contracts to the Most Economically Advantageous Tender (MEAT) greatly influences the procurement strategies used by NSS.

I think the challenge for us is because we are a public organisation, we're funded by the public trusts and public money, there's a whole host of other things around legislation that we obviously have to comply with. There is about fairness and equality within the market we operate. But there is also things around the due-diligence that we have to do to make sure we spend our money wisely (CMI).

This best value and cost-saving strategy was evidenced by the secondary data, which included tendering process documents. The low-cost strategy is part of the reason why single-supplier awarding accounts for about 70% of their frameworks. Single-supplier frameworks promote compliance and the more purchases through the frameworks put in place by NSS, the more savings the NHS can achieve. Another reason for using single-supplier frameworks are the use of distributors, which allows them to award tenders for lots instead of individual items. Respondents state that single-supplier frameworks help to build stronger, collaborative relationships. There is recognition that purchasing power is valuable and that public perception is regularly considered.

There is also a push to make sure we can use our purchasing power in the right way, so for example things like sustainability, you know, can we actually drive that agenda? Can we drive it for economic benefits to Scotland? (CMI).

Scottish suppliers are currently cost competitive in the marketplace for PPE given the global rise in costs, but some participants discussed how that could change in the future.

As a taxpayer you would be horrified if you found out that the NHS trust were spending 10x over the costs to secure masks supplying Scotland — you would probably be horrified. Right now, you'd be like “oh, that's fine”. But in ten years' time... (CPI).

However, there are also benefits to being in the public sector, such as collaboration with the government and assistance in times of disruption.

When we end up in a scenario where we have that kind of significant disruption, governments got a very important job to play because it needs to take an overview, understand what's happening and what proactively to do to be able to mitigate that (SG1).

Collaboration between NSS, Scottish Government and quangos was critical during the pandemic. Scotland was able to charter planes in order to bring in PPE faster to ensure no stock-outs. Collaboration with quangos directed by the government also allowed field agents to perform on-the-ground due-diligence in China. This relationship supported the development of new SCs such as Scottish manufacturers repurposing their operations to contribute to the PPE supply effort. These relationships between Government and business communities were established, and not just driven by the pandemic.

So businesses in most cases that we were talking to about repurposing for manufacturer we already had long established relationships with them through the economic development agencies, which meant that we were able to have those conversations very quickly in terms of what the demand side looked like. Or we could same day, have good conversations with manufacturing businesses and understand their challenges to rise up and help support, so that network that we had in place was very helpful (SG1).

Endorsement for maintaining collaboration comes from respondents as part of the lessons learned, due to the potential for more economic opportunities, being agile to change and knowledge sharing.

...we need to maintain that level of interaction between us all, and that kind of sharing of staff, sharing of ideas, sharing of best practice (CP1).

At a government level, the experience of working in healthcare SCs during COVID-19 has offered valuable lessons about supplier capability and SCs that apply beyond healthcare in Scotland.

I suppose that, definitely, what we've learned from that process is something we can apply in other supply chains...where we are spending public money, and there is the capability to work with manufacturers and supply chains to bolt things together that are able to deliver a need the public sector's got. So, I think there's been direct impact in terms of jobs and economic input, but also the ways of doing that I think have been very valuable lessons as to how we can do that across other sectors in the supply chain (SG1).

Discussion

The COVID-19 pandemic has seen SCs globally face unprecedented disruption. Our study provides timely contributions in providing a single case study on how resilience is evident in a

public sector healthcare SC and the lessons learned from this test of resilience driven by the COVID-19 pandemic.

Our first contribution is to the existing literature base in providing empirical research on SCRES (Scholten and Schilder, 2015; Chowdhury and Quaddus, 2017). Work on manufacturing SCs dominates with little attention given to service SCs (Tukamuhabwa *et al.*, 2015; Mandal, 2017; Getele *et al.*, 2019), such as healthcare (Graves *et al.*, 2009; Mandal, 2017; Rubbio *et al.*, 2019). In investigating NSS who provide procurement and supply for the NHS in Scotland, our contribution is further enhanced by focusing on a public health context (Stewart *et al.*, 2009; Pettit *et al.*, 2019) and national level supply chain (Rowan and Laffey, 2020).

In responding to calls for research, we can answer our first research question in illustrating how SCRES is demonstrated in a healthcare SC when faced with pandemic disruption. A lack of preparedness for pandemics was previously perceived (Dasaklis *et al.*, 2012; Ekici *et al.*, 2013), despite requiring a healthcare response. In answering this first research question, two themes were presented in the data analysis: ‘organisational readiness’ and ‘evidence of resilience in response’. Given the global scale of demand and impact of the pandemic, it could be argued that most nodes in the global PPE SC were not resilient to COVID-19, as many of the existing suppliers failed to meet their customers’ demand. However aligned to Pournader *et al.* (2016), individual tiers in the SC can be limited in terms of resilience but the overall SC can be resilient. This was very much evident in this study. In terms of NSS as a node in the SC (Cardoso *et al.*, 2014; Martins de Sá *et al.*, 2019), Martins de Sá *et al.* (2019) suggests that SCRES can be established by a resilient node downstream in the SC, and the PPE SC could be viewed as resilient due to NSS downstream actions and activities.

NSS demonstrated both pre-existing resilience aspects in considering organisational readiness and in their response to the disruption. Pre-existing aspects such as collaboration with suppliers, flexibility, redundancy, and SCRM, are cited in literature as critical elements of resilience (Hohenstein *et al.*, 2015; Ali *et al.*, 2017). These important aspects of resilience were evident in their response including their ability to create redundancy through ‘make’ and ‘buy’ strategies supported by collaborative efforts with the quango and Scottish Government. The agile nature of collaboration also supported flexibility in identifying new suppliers mid-pandemic in China for PPE, as the quango were able to do due-diligence for quality and specification. Having access to Scottish Government support and manufacturing advisory

services for identifying suppliers in Scotland for PPE production helped. Resilience in the form of social resources was also highlighted, as the staff themselves were resourceful, resilient, and demonstrated change management capabilities (Ates and Bititci, 2011; Pal *et al.*, 2014) in adjusting to new ways of working and technology adaptation.

Although flexibility and agility were shown in how NSS responded to their existing NHS customer base when demand vastly increased, flexibility and agility were also evident in the set-up of new supply chains and warehousing facilities in covering PPE supply for the entire social care sector (including public and private actors) across Scotland. This showed not just response, but also growth to extend the supply network (Hohenstein *et al.* 2015).

In answering the second research question, three themes are evident in the data analysis: 'Lessons Learned', 'Healthcare Context' and 'Public Sector Context'. As a result of the healthcare and public sector contexts, all three themes overlap in their impact on NSS and learning from COVID-19.

There are some consistencies found in this study of NSS and existing literature on healthcare supply chains. Despite undertaking a vulnerability analysis on their PPE supply chain early in the crisis and demonstrating reasonable understanding of the scope of the SC, visibility continues to be highlighted as to where there have been risks, and there will be further lessons to be learned for NSS, as has been reported elsewhere (Kwon and Kim, 2018). Products such as PPE were sourced internationally, pre-pandemic (Dai *et al.*, 2020). NSS, like other healthcare agencies, report that the use of distributors is common (Graves *et al.*, 2009; Kwon and Kim, 2018) as this means tenders are awarded in lots and it is viewed to support closer relationships. However, unlike previous findings showing that long relationships result in visibility (Scholten and Schilder, 2015), the approach of the distributor relationship is viewed to compromise visibility with second and sub-tiers of the supply chain being a cause for concern. The lack of visibility over tiers in the supply chain is well documented (Pettit *et al.*, 2013; Pournader *et al.*, 2016). In assessing lessons learned from COVID-19 as part of recovery to support future readiness, we evidence that collaborative relationships pre-pandemic have not positively impacted visibility. Therefore, this forms our first proposition:

Proposition 1: Specific analysis of tiers will uncover vulnerabilities, even in established collaborative relationships, which can inform the development of future readiness and resilience strategies.

Awareness of these vulnerabilities and following through on lessons learned when demand eases means increasing visibility will allow NSS and other healthcare agencies to better understand each node in their SCs (Jüttner and Maklan, 2011; Brandon-Jones *et al.*, 2014; Hohenstein *et al.*, 2015) regarding their domestic or international location.

In addressing vulnerabilities in SCs extending to China and the Far East, NSS were able to source from providers in Scotland, resulting in new capabilities for companies in the country. This now results in questions over future options of rebalancing SCs and using multiple suppliers to mitigate single sourcing risks. Rebalancing the SC to include supplier diversity and multiple suppliers in different geographical locations is recommended (Trkman and McCormack, 2009; Tukamuhabwa *et al.*, 2015). Response diversity would mean suppliers having different contingency plans in place, rather than standardised responses to disruption (Kahiluoto *et al.*, 2020). Here, however, it is useful to remember the distinctiveness of healthcare SCs as spreading supplier risk is not straightforward with clinical preferences influencing adoption and use of products (McKone-Sweet *et al.*, 2005). Respondents also discussed this.

Collaboration was evidenced as a critical factor for NSS resilience mid-pandemic. As the Scottish Government has done, standing up domestic SCs in Scotland has built national resilience (Stewart *et al.*, 2009), and is one of the recommended strategies suggested by Patel *et al.* (2017) and Rowan and Laffey (2020) to improve PPE acquisition. NSS, Scottish Government, and quangos had not previously collaborated on this scale until the pandemic and the collaborative efforts meant PPE supply continued, despite being subject to severe disruption. Few examples exist of mid-pandemic government and supply network response, but collaboration between government and healthcare actors has been valuable in responding to the COVID-19 public health crisis, as has been evidenced in Canada (Webster, 2020). The collaborative efforts of NSS, Scottish Government, and quangos supported knowledge sharing and monitoring capabilities which continue to be highlighted as crucial to resilience (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Pettit *et al.*, 2013; Scholten and Schilder, 2015). This results in our second proposition:

Proposition 2: Healthcare, government, and government agency collaboration is critical in supporting resilience during a pandemic response.

Limitations and Areas of Future Research

Data were collected from the pandemic period. The study is therefore a ‘snap-shot’ in time, and the context is in a single public sector based healthcare SC. Findings of readiness, growth, response and recovery may differ in other contexts and over longer periods. A longitudinal study would be able to firmly assess all four phases of resilience including how recovery then informs future readiness strategies. Additionally, our focus was on NSS resilience activities so suppliers in the network were not part of this research. Consideration of the focal firm, domestic, and international suppliers’ activities could shed further light on a network response to the pandemic. This would allow for further assessment if collaboration definitively supports greater visibility given we had both negative and positive influences of this from our case study. There are opportunities for comparative research within healthcare SCs in both public and private sectors to encompass evaluation of resilience at regional or national levels.

Our focus was firmly on a public sector and therefore a government funded entity, in a developed country where money and resources were available to support procurement and SC activities. There is now greater scope for comparative work on developed and developing country responses as a result of our literature review providing an overview of healthcare SCs. We briefly highlighted ethical issues with access to medical equipment driven by the ability of developed countries purchasing power (Dai *et al.*, 2020; Garber *et al.*, 2020). Purchasing power impacts redundancy and responsiveness, and could compromise other health systems ability to demonstrate resilience.

Managerial Implications

Although healthcare SCs are viewed as distinctive, the centralisation of procurement such as that viewed in NSS, is an approach across sectors so there is potential to understand this further in assessing resilience. Furthermore, the work undertaken to link manufacturing and healthcare in responding to pandemic disruption has relevance in lessons learned for other SCs where there is endorsement for greater public and private sector collaboration. Waves of infections of COVID-19 are affecting countries globally, and are expected over the next two years. However, there are concerns raised about the capacity of staff to work under extreme demand pressures.

The role of human resources (HR) was critical in supporting NSS during the pandemic response and as such, these are the focus of our managerial implications. HR surge capacities should be pre-determined and clear responsibilities defined in business continuity planning (Ghadge *et al.*, 2012; Ali *et al.*, 2017). This would allow for better human resource management (HRM)

and quick reconfiguration of internal resources as necessary when faced with disruption, which supports an agile and proactive response (Ambulkar *et al.*, 2015; Sawyerr and Harrison, 2019). COVID-19 created a high-pressure, high-stress work environment for NSS staff trying to manage excessive demand, which can have detrimental effects on staff health and wellbeing (Leite *et al.*, 2020). Medical shortages in a time of crisis have a detrimental impact on staff resulting in burnout (Rachiotis *et al.*, 2014). The psychological impact on staff of responding to prolonged crisis, allocating resources and the ethics of this are evaluated with acknowledgement of these not being adequately addressed over the past 10-15 years (Fraser *et al.*, 2015). Rotating teams are suggested (CIPD, 2020), which would allow for breaks and may prevent burnout. Although the importance of HRM and a positive culture has been briefly mentioned in SCRES (Pal *et al.*, 2014; Sawyerr and Harrison, 2019), staff wellbeing during SC disruptions has not been a focus. This leads to our final proposition:

Proposition 3: An increased focus on staff, with the potential for rotating teams to ensure downtime, is required to support resilience but avoid staff burnout.

Conclusion

The findings of this study contribute to empirical research on SCRES identifying readiness, response and growth. This included illustrating resilience strategies such as agility, flexibility, redundancy, and their application in the healthcare SC. We consider lessons learned which relate to recovery aspects in resilience. Although focused on NSS, data also came from the wider public sector enterprise in identifying elements of resilience in the COVID-19 response. Through this, collaboration is evaluated as being key to resilience and especially in supporting growth; the public sector context was highlighted as an enabler of this collaboration. These findings and our propositions allow managers to consider not just wider SC vulnerabilities, but also internal risks to operations that can affect resilience.

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Appendix 1 Interview Protocol

Broad aspects of the event impact

In your opinion, in what ways did COVID-19 cause healthcare supply chain (SC) disruption?

How did the SC react to the huge increases of demand for PPE? *What was the root cause of this?*

Readiness

Prior to COVID-19, had NSS dealt with SC disruptions? *How did NSS SC react to those disruptions?*

Prior to this year, would you say that risk management has been part of the culture? *In what ways has this changed due to COVID-19, if at all?*

Do you have a formal risk identification and prioritisation process? What about business contingency plans? *Can you provide some examples? Did any of that help with such a widespread long-lasting pandemic?*

Was a formal response team put in place for COVID-19? How did internal communication work regarding the COVID-19 response? *Did it work well enough, if not how could it be improved?*

What did NSS do in anticipation of COVID-19 cases appearing in Scotland? *(Between January and mid-March)*

Were actions taken by suppliers in anticipation of COVID-19? *Did they proactively inform you of possible shortages?*

Before COVID-19, what was supply visibility like? Did this change? *Was it easy to find out from suppliers how much inventory they had on hand and could produce? Were formal lines of communication set up with suppliers?*

Do you think there are any unique procurement challenges within healthcare?

Do you think the healthcare SC was prepared for such a disruption?

Resilient and adaptive operations

How did NSS adjust procurement methods in order to continue delivering PPE to health boards?

Did long-term relationships with suppliers benefit you during this disruption? *Were these suppliers more willing to collaborate than other/newer suppliers?*

How did NSS react to PPE shortages in the marketplace? What happened in situations where a supplier was not able to fulfil an order? *Were there other suppliers (with existing contracts) that were able to fulfil orders?*

Explain the collaboration efforts with the government? *How did those collaborative efforts help mitigate the disruption?*

In your opinion, were there ways in which the SC performed well or was resilient?

Response

Can you tell me about the 'PPE push' SC that was established? What capabilities allowed you to accomplish that? *What types of issues did you run into? How did you overcome staffing issues, transit issues etc.?*

Growth

What were the challenges involved in supplying the social care sector?

Recovery

What actions do you think should be taken to increase healthcare SC resilience?

In terms of sourcing, how does this change your existing contracts? *Will this be more focused domestically? Single or multiple sourcing?*

What are the key lessons learned from this pandemic that can be applied to future SC disruptions?

End of Interview Question

Is there anything else you would like to tell me?

Table I: Interviewee's and interview data codes

#	Role	Years in Role	Data Code
<i>National Services Scotland (NSS)</i>			
1	Senior Manager	15	SM1
2	Category Manager 1	4	CM1
3	Category Manager 2	13	CM2
4	Category Manager 3	11	CM3
5	Project Manager	11	PM1
<i>Scottish Government</i>			
1	Business Manager (<i>quango</i>)	15	CP1
2	Scottish Government Minister	2	SG1

Table II: Theme Definitions

Themes	Theme Defined	Interview Excerpts
Unprecedented disruption	The COVID-19 pandemic caused a dramatic increase in the demand for PPE as it quickly spread across the world resulting in global supply shortages. Unique challenges for NSS included the criticality of their response and difficulties in forecasting.	<i>I hate using the phrase, but it is such an unprecedented situation to deal with that you wouldn't be able to plan or ever anticipate the jump in demand... these plastic face visors - we bought 900 of those last year... and we've bought 7 million so far this year. (CM3)</i>
Organisational readiness	In assessing the organisation's level of readiness, it is clear NSS had pre-existing aspects of resilience, which aided their response, but there were also vulnerabilities both within the organisation and within their supply chain.	<i>...it's a global supply chain, but it's a small world - that works to an extent. But technically you know if your product is 8000 miles away from where you actually are based then there are risks associated to that clearly, and you're not close to them. (CM2)</i>
Evidence of resilience in response	Although the PPE supply chain may not necessarily be considered resilient, NSS as an organisation displayed many traits of resilience in their response strategy.	<i>So, was it resilient? Yes, it was because we never ran out of PPE. But that's because of a huge herculean effort of Scottish, UK, European, basically the whole global economy all turned its attention to supplying that PPE in a time of crisis. (CP1)</i>
Adaption to post-disruption environment	As the COVID-19 pandemic is still on going, NSS has not begun its transition into recovery but they have already identified lessons learned and are aware of the challenges they will have adapting to the post-COVID-19 environment.	<i>So the next challenge for us is how we balance all the activity that we've done and revert back to our BAU... As in are we buying mostly from the Far East through the supplier network that we have. Or do we do something different? But that's very difficult to do in public procurement... But to be quite honest, we're still in a PPE provision mode... (CM2)</i>
Healthcare context	There are unique challenges to building resilience within the healthcare context such as the product diversity and clinical preference impact on procurement strategies.	<i>One of the key things when you're dealing with any products, is the user, especially in the healthcare setting, if they have to use products they're not familiar with. It can make them a bit nervous; it introduces risk. (SM1)</i>
Public sector context	There are benefits and challenges of working within the public sector including the importance of cost saving, adhering to legislation and the opportunity to use their purchasing power to build national resilience.	<i>So private companies can procure from whoever they want but public bodies such as NSS have to follow particulate procurement guidelines... we have to be conscious of the fact that we have to be not only getting best cost, best value but can we build in additional factors that allow us to maintain security and resilience that kind of balance that need for lower cost. (CP1)</i>

Table III: Themes, Supporting Sub-themes and Codes

Theme	Sub-themes	Codes
Unprecedented disruption	Increased demand	• Panic buying
	Supply shortages	• Market profiteering • Marketplace competition • Price fluctuation (increase) • Restricted export
	Unique challenges (within contexts)	• Criticality of response (life or death) • Difficult to prepare for (protect against) • Impossible to forecast • Internal constraints
	Speed and length of impact	-
Organisational readiness	Pre-existing aspects of resilience	• Capacity • Collaboration with suppliers • Efficiency • Flexibility • Redundancy (in the form of a pandemic stockpile) • SCRM culture • IT capability
	Organisational vulnerabilities to disruption	• Lack of organisational visibility
	Supply chain vulnerabilities to disruption	• Lack of supply chain visibility • Lean supply chains • Reliance on Far East
Evidence of resilience in response	Continued to meet demand	-
	Increased customer base (social care sector)	-
	Aspects of resilience	Agility • Collaboration • Concerned about sustainability • Efficiency • Flexibility and adaptability • Learning-oriented • Velocity
	Redundancy (make and buy strategy)	• Created buffer stock • Reshoring
	Social resources (HR) - staff efforts	-
Adaption to post-disruption environment	Awareness and learning	• Pandemic is still on-going (uncertainty) • Lessons learned
	Challenges going forward	• Assessing response and actions taken • Balancing trade-offs • Maintaining resilience long-term • Providing for social care sector going forward • Risk reducing measures
Healthcare context	Customer requirements	• Clinical preference • Customer focused • Procurement requires collaboration with clinical staff • Safety and importance of quality
	Product diversity	• Some items are very complex • Strategy varies per category
Public sector context	Adhering to legislation	• Requirement of transparency • Sustainability
	Importance of cost-saving	• Best value or MEAT strategy • Lack of funding • Mostly single-supplier strategy
	Use of purchasing power	• Level of spend