Expert Report for the UK Covid-19 Public Inquiry

Module 5: Procurement and distribution of key equipment and supplies

Supply chains

Author: John Manners-Bell

Author statement

"I confirm that this is my own work and that the facts stated in the report are within my own knowledge. I understand my duty to provide independent evidence and have complied with that duty. I confirm that I have made clear which facts and matters referred to in this report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinions on the matters to which they refer."

John Manners-Bell

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Preamble

1. John Manners-Bell (56) is Chief Executive of global market research organisation Transport Intelligence Ltd, Founder of the Foundation for Future Supply Chain and formerly Honorary Visiting Professor at the London Metropolitan University's Guildhall Faculty of Business and Law as well as an adviser to the World Economic Forum and United Nations.

2. He has over 35 years' experience working in and analysing the global logistics sector. John started his working life as an operations manager of a logistics company based in the UK. Prior to establishing Transport Intelligence in 2002, he worked as an analyst in consultancies specialising in international trade, transport and logistics. He also spent a number of years as a manager of global express and logistics company, UPS, in a strategic marketing and communications role.

3. John holds an MSc in Transport Planning and Management from University of Westminster and is an Associate of King's College London where he studied Classics and Theology. He is a Fellow of the UK Chartered Institute of Logistics and Transport and former Chair of the Supply Chain and Logistics Global Advisory Council of the World Economic Forum. He has also advised the European Commission Directorate-General for Energy and Transport, United Nations Trade & Development and has appeared before the House of Lords Select Committee for Brexit. A freeman of the City of London, he is a member of the livery company, the Worshipful Company of Carmen, the world's oldest transport organisation.

4. John has written seven books on the industry – 'An Introduction to Global Logistics' (two editions), 'Supply Chain Risk Management: Understanding Emerging Threats to Global Supply Chains' (four editions), 'Logistics and Supply Chains in Emerging Markets', 'Supply Chain Ethics', 'The Logistics and Supply Chain Innovation Handbook' (two editions), 'The Death of Globalization' and 'The Good Supply Chain'. His second book, 'Supply Chain Risk Management' won the Mention Speciale ACA-Bruel Prize for supply chain literature in 2014 and the Royal Logistic Corps Foundation award in 2015.

5. John is frequently quoted in the trade and national press as well as appearing on TV and Radio. He speaks regularly at conferences in countries around the world.

Executive Summary

6. The Covid-19 pandemic exposed many of the frailties of PPE and healthcare equipment supply chains. Off-shored, out-sourced, global and complex, supply chain structures had been developed during a period in which cost considerations were prioritised over resilience. During 'business-as-usual' times a focus on value was understandable. Demand was constant and predictable and supply was plentiful. However, the same structures proved unable to cope with the massive demands placed upon them by a global pandemic.

7. Section 1 examines the context in which PPE and healthcare equipment supply chains have evolved, identifying the key business trends which influenced the development of low inventory, globalised and increasingly fragile supply chains.

8. Section 2 discusses how supply chains can be made more resilient looking specifically at the PPE and healthcare equipment sector.

9. Section 3 drills down more deeply into the dynamics of the sector examining upstream dependencies, the role of international logistics and downstream distribution and procurement models.

10. Section 4 considers the UK's preparedness for a pandemic and the steps which had been taken to ensure resilience.

11. Section 5 sets out the performance of supply chains throughout the pandemic period and highlights many of the challenges faced.

12. Section 6 looks at the steps which have been made to address some of the shortcomings exposed by the pandemic and the ways in which procurement and distribution models have since changed.

13. Based on the evidence provided in the report, I have made a number of recommendations relating to changes in government policy and operational practice. These recommendations are consolidated at the end of the report.

Section 1: Placing Healthcare Equipment supply chains in context

14. The first section of the paper examines the influence which developments in industry-wide supply chain strategy and business theory had upon the PPE and healthcare equipment sector in the UK. It deals with the relationships which have been created as products flow from 'upstream' suppliers, often based remotely, to 'downstream' customers. At each stage of the process, value is added by each supplier until raw materials are transformed into finished goods. This involves multiple manufacturers, distributors and logistics service providers on an international basis, as materials, intermediate goods and finished goods are moved around the world before distribution to the end-user. In the case of the PPE and healthcare equipment sector, this is often a hospital, primary or social care setting.

15. This process is facilitated by flows of data up and down the supply chain which allows all parties to plan manufacturing schedules, gain insight into demand and track deliveries of

product. This in turn enables supply chain managers to reduce levels of unnecessary inventory within the system, reducing costs whilst, in theory, still able to meet customer demands.

16. A good rubric to judge the effectiveness of a supply chain is by its ability to deliver:

    - the right products;
    - in the right place;
    - at the right time;
    - in the right condition;
    - in the right quality;
    - at the right price.

17. An inability to meet demand is most likely to be caused by a combination of inaccurate forecasting; supplier shortages; under-ordering; inadequate safety stock (also called 'buffer' stock); delivery issues and product quality problems. All of these issues were relevant to the PPE and healthcare equipment crisis experienced in the early days of the pandemic.

18. A feature of modern manufacturing has been the off-shoring of production from Western countries to low cost markets based primarily in Asia and, as in the case of PPE and healthcare equipment, specifically in China. Manufacturers have developed what are called 'virtual' networks, focusing on the design and marketing of products, whilst out-sourcing production to a small number of 'Tier 1' suppliers. In turn, these companies manage a larger number of 'Tier 2' suppliers to produce sub-assemblies and components. This process can continue to Tier 5 suppliers and beyond. Whilst there are many economic benefits resulting from this structure in terms of cost and the ability for suppliers to specialise in certain manufacturing techniques, it creates high levels of opacity. This is a problem as supply chain procurers (for example, Health Trusts or Devolved Administration (DA) central buying organisations) have little visibility of risks related to dependency on single suppliers; the impact which suppliers are having on the environment or the treatment of their workers.

19. Low levels of visibility are also problematic for suppliers. Unforeseen end-user demand, often caused by a lack of data sharing, results in the so-called 'bull whip' effect in which inaccurate demand data is amplified at every stage of the supply chain resulting, in a worst case scenario, in global market dysfunction. During the Covid-19 pandemic, for instance, procurement organisations had little visibility of usage of PPE or healthcare equipment at a hospital level and so were unable to place accurate orders with their suppliers.

20. Transport and logistics are an essential element of supply chains. Remote, off-shored manufacturing is based on low cost, efficient and reliable international containerised shipping and air cargo. During the pandemic, transport networks came under intense pressure as systems were overwhelmed by demand for consumer goods and the

cessation of many passenger services reduced air cargo capacity. On top of this, networks were also affected by Covid-19 sickness in the workforce.

21. The evolution of supply chain practice has led to an increase in other risks. Whilst virtual manufacturing networks benefit from low cost labour; the ability to scale up production quickly; and lower inventory holdings, they have also:

    - decreased levels of management control (including quality);
    - increased distances to market;
    - increased dependence on foreign suppliers based in emerging markets (sometimes adversarial) with nascent compliance regimes; and
    - reduced safety stock.

22. The impact of the Covid-19 pandemic, along with increased recognition of the impact of geo-political events, natural disasters and a range of other risks, has led to the adoption of what has been termed 'Supply Chain 3.0', which utilises a number of new technologies (eg automation and 3D Printing) and business practices (such as 'China Plus' sourcing) to mitigate some of these risks.

23. Pandemics have a system-wide impact on supply chains, affecting demand and supply variables, including logistics and transportation elements. In order to withstand such disruption in the future, PPE and healthcare equipment supply chains will need to be more agile to unfolding events. How this can be achieved is discussed in the following section.

Section 2: Risk and resilience of healthcare and related equipment supply chains

24. In order to mitigate the impact of geopolitical, economic, technological, environmental and, of course, pandemic risk, supply chains must be made more resilient. This can be achieved by a range of measures including building strong and collaborative supplier relationships; increasing visibility through better use of data; increasing the diversification of the supplier base geographically and developing robust contingency plans. 'Lean' or 'low' inventory supply chains are more vulnerable to disruption as less stock is held in reserve should continuity of supplies be affected for any reason. However, holding more inventory also comes with financial costs as well as the risk that stock might go out-of-date or become unfit for purpose due to changing end-user needs.

25. In design, PPE and healthcare equipment supply chains should be 'risk-agnostic', that is they should be prepared for all rather than specific disruptive events. These include, amongst others, economic (e.g. industrial action or a rise in shipping rates); natural disasters (e.g. flooding or tsunamis); geopolitical conflict; ethical and societal (e.g. the treatment of workers in PPE factories) and criminal (e.g. theft or counterfeiting).

26. Standards exist which allow organisations to benchmark their own practices and operations against international best practice, such as ISO 31000 and ISO 22301. These standards identify steps which should be undertaken to identify potential disruptive events; assess their impact; prioritise response and manage and monitor the

effectiveness of the process put in place. By mapping the probability of an event against the likely severity of its disruption, a supply chain risk manager can more effectively allocate resources and manage time.

27. Two of the key steps undertaken by the UK and DA governments to mitigate supply chain disruption prior to the pandemic involved building stockpiles of PPE and healthcare equipment and putting in place Just in Time (JIT) manufacturing contracts with suppliers. However, as discussed throughout the paper, the measures were not sufficient to deal with the magnitude of the disruption.

28. The UK was not alone in facing supply chain dysfunction. At the root of the vulnerability was a model which was dependent on off-shored production and sourcing from remote, low cost markets, dominated by China. In the cases when governments had established stockpiles (including the UK's), they were intended for influenza pandemics and proved insufficient to deal with the needs of healthcare workers facing Covid-19. Many countries in Europe had highly fragmented and devolved procurement organisations which were incapable of coping with the complex and quickly developing PPE and healthcare equipment crisis. In the US, the market was confused by multiple private and public health organisations, many of which competed against each other for supplies in the open market.

29. Price volatility has also had a significant impact on PPE supply chain development. In a 'business-as-usual' period, the low value of PPE means that it makes economic sense for it to be manufactured in low cost regions, although with the attendant risks already discussed. During a period of disruption which results in high demand, a high price point makes it economically viable for PPE production to be re-shored providing greater surety of supply. However, when the market returns to 'normal' (as it did rapidly post-Covid-19) subsequent falls in the price of PPE make it difficult for Western-based manufacturers to compete on the global market. Without government support in one form or another or increasing levels of automation reducing the need for a low cost labour force, long term, large scale domestic PPE production will be difficult to achieve.

30. However, re-designing supply chains to be 'circular' could have major benefits in terms of resilience. Present PPE supply chains are 'linear', originating largely in Asia and ending in landfill or energy-from-waste incinerators. The development of new materials and cleaning processes could lead to the safe re-use of certain types of PPE reducing volumes of new product required. It would also reduce the environmental impact caused by the disposal of single use plastics.

Section 3: The structure of the PPE and healthcare equipment industry

31. China is the dominant manufacturing centre accounting for 40-60% of production of coveralls, masks, aprons, eye protection and slightly lower levels in other sectors. Before the pandemic, the medical gloves market was the exception, with Malaysia and Thailand accounting for 85% of the world's production between them. The USA is the only other major manufacturing market with presence in most sectors, accounting for 20-25% of supply although sizeable production exists in other individual markets, including European countries such as Germany and France. The latter rely on automation and new technologies to achieve competitiveness against lower cost producers.

32. Upstream supply chain dependence on sourcing from a single country is a major risk due to political decisions which may restrict supply and the potential impact of international transport choke points. Trade figures included in Section 3 show the UK's dependence on PPE and healthcare equipment exported from China, using Covid-19 test kits and face masks as examples. Trade figures also show the more complex market which exists for surgical gloves, demonstrating that supply chain managers must 'drill down' deeply to identify dependencies, including those of raw materials. The UK's reliance on China for PPE and healthcare equipment has prompted a discussion over whether supply chains should (or could) be 'de-coupled'.

33. Downstream distribution is handled very differently across the four nations of the UK. In England, 226 Health Trusts are served by NHS Supply Chain although individual Trusts have the freedom to procure their own PPE and healthcare equipment if they prefer. This operating model, which was established before the pandemic, was suspended when it proved unable to cope with the pressures of increased demand and limited supply. A new model, the Parallel Supply Chain, was developed to supply 58,000 individual health settings directly. In Scotland, NHS Boards are supplied primarily by NHS National Services Scotland (NSS); in Wales healthcare organisations are supplied by NHS Wales Shared Services Partnership (Shared Services) and in Northern Ireland, the centralised role is filled by Business Services Organisation Procurement and Logistics Service (BSO PaLS).

34. In terms of international transportation, the UK is very well integrated within the global trading environment. It has a highly developed freight forwarding, express parcels, road freight, shipping and air cargo sector, providing high quality and innovative logistics services. However, the UK's insular geographic characteristics means that it is at risk from disruption to air and sea services and imports can be delayed by administrative processes at Customs, border controls, trading standards, or by phytosanitary checks and security screening.

35. Supplier relationships are critical to a resilient supply chain. Strong partnerships, openness and honesty encourage data sharing throughout the supply chain and this not only underpins efficient operations in business-as-usual times, but importantly helps mitigate the impact of disruptive events. However, at the same time, procurement organisations need to be able to access the open market when product shortages exist.

36. Tender evaluation is an important tool in ensuring supply chain resilience. It provides insight into a supplier's preparedness for disruption; its financial robustness; the visibility it has of its own suppliers; its risk mitigation procedures and policies related to ethical and environmental practices.

37. The provision of data is critical to ensuring resilience. Best practice in the industry involves the use of 'Control Towers' to analyse shipment data generated by consignments as they move along the supply chain. This allows managers to make decisions, increasingly supported by Artificial Intelligence, that can prevent product shortages, avoid delays, and fulfil customer needs whilst reducing inventory.

Section 4: Supply Chains before the pandemic

38. The UK and DA governments were well aware of the threat posed by pandemics prior to Covid-19. A number of Pandemic Influenza Preparedness Plans (PIPPs) had been developed, but these were limited to influenza. In addition, cross-government exercises had been undertaken to test levels of preparedness. Learnings from these exercises led to the preparation of a draft Pandemic Influenza Bill which was used as the basis for the Coronavirus Act.

39. Of most relevance to the supply of PPE and healthcare equipment was the establishment of emergency stockpiles in each of the four nations. These were in addition to a 'Brexit' stockpile which had been established to cope with the potential consequences of leaving the EU without a trade deal in place. JIT manufacturing contracts were also agreed which, it was hoped, would enable stockpiles to be replenished rapidly in the event of high levels of demand.

40. Despite the plans, as the DHSC itself admitted (DHSC, 2020), important differences between Covid-19 and influenza meant that these contingencies were inadequate to deal with the needs of healthcare workers during the pandemic. A review of other Western countries showed a similar situation existed elsewhere.

41. Prior to the Covid-19 pandemic, procurement and distribution structures had been established to improve productivity, efficiency and standardisation. In England, procurement was (and still is) undertaken by NHS Supply Chain, a centralised buying organisation established following a report by Lord Carter of Coles, as well as by individual Health Trusts. In the DAs, procurement was, and remains, predominantly undertaken by centralised, government-owned organisations.

42. Consolidation of buying power in centralised procurement organisations can increase market leverage, reducing costs and increasing influence over upstream suppliers. However, despite this, many Trusts in England still prefer to buy their own PPE and healthcare equipment as they believe their own buying functions gives them more flexibility; the ability to tap local suppliers; better prices; more reliability and speed of supply.

43. The UK's manufacturing sector, although very substantial, was not in a strong position to establish or scale up production of PPE and healthcare equipment. Years of off-shoring of lower value production processes to remote low cost labour markets had been undertaken in order to focus on the design and manufacture of high value goods. In contrast, other countries with substantial textile sectors were able to re-deploy resources to the manufacture of certain PPE products, such as face masks.

44. A further factor inhibiting an effective response to the pandemic was a poor visibility of fragmented inventory holdings throughout the UK. In addition to the emergency stockpiles, there were 'business-as-usual' stocks held by healthcare organisations, Trusts, Boards and centralised buying organisations. As well as these, there were stocks held by distributors, manufacturers and government departments (such as the Ministry of Defence).

Section 5: Supply Chains during the pandemic

45. A major problem faced by healthcare organisations in the early days of the pandemic was establishing the volume of PPE and healthcare equipment that would be required to meet demand. Unknown infection rates combined with changing technical guidance on the frequency of use of PPE had a major impact on forecasts and orders. This combined with multiple procurement organisations placing multiple orders, overwhelming the global market and the international logistics sector. As emergency stockpiles soon depleted, any shipments which arrived were immediately 'pushed out' to healthcare providers. The market dysfunction led to a huge spike in prices in April 2020, before dropping throughout the rest of the year as supply increased and demand fell away.

46. The situation was worsened by reductions in Chinese production and exports in the early part of 2020. Impacted both by Covid-19 sickness in the work force; a focus on meeting domestic needs and restrictions on exports by the government, Chinese manufacturing was unable to meet global demand. In Europe, export bans were put in place by Germany and France (amongst other countries) and subsequently by the European Commission. Over 220 trade measures were put in place globally restricting the export of PPE and healthcare equipment.

47. International transport was unable to keep up with demand. Air cargo capacity was affected by the reduction in air passenger services to and from China and other major production locations, although charter flights, the re-purposing of passenger aircraft to freight and military operations started to fill this gap. Customs border agency resources, affected by Covid-19 sickness themselves, came under pressure from the volume of PPE and healthcare equipment being moved; the testing required and the extra administration involved in dealing with new, inexperienced traders, often shipping PPE for the first time. The 'last mile delivery' of product was also problematic and the Parallel Supply Chain operation used a combination of public and private resources to distribute consignments to healthcare organisations and primary/social care providers.

48. Complexity of international standards meant that it was hard for border agencies, trading standards authorities and other parties involved in international trade to ensure that products were compliant with quality standards. Many millions of items of PPE were rejected on arrival in Europe which contributed to a lack of visibility of stock levels and inaccurate forecasts.

49. By May 2020, the situation was gradually improving. Central procurement organisations in the UK had a greater visibility of demand for PPE and healthcare equipment from health and social care providers, allowing them to more accurately replenish stocks.

50. However, accuracy of forecasting demand remained a major challenge throughout the pandemic. Order volumes had to take into account changing guidance on the frequency of use of PPE; hospitalisation rates; infection transmission rates; vaccine programme roll outs and government policies (such as stay-at-home orders). Despite the complexity of the task, multiple models were developed in the UK and elsewhere, although their usefulness can be questioned given the massive over-ordering which was undertaken.

51. The Parallel Supply Chain, already referenced, was established to replace the fragmented approach to PPE and healthcare equipment procurement and distribution which existed

prior to Covid-19 pandemic. Its role included finding new suppliers of product; establishing direct links with manufacturers; dealing with potential UK suppliers; ensuring compliance to quality standards and distributing shipments to end-users in the health and social care sectors. However, it was criticised for being overly bureaucratic and slow to react; ignoring offers of help from UK manufacturers; procuring sub-standard products; and over-ordering and over-paying for PPE and healthcare equipment.

52. In response to fears that there would be a shortage of ventilators, the UK government established the 'Ventilator Challenge'. This brought together many UK manufacturers in an enormous effort to design and produce complex medical equipment requiring thousands of components within a short time period. In the end, many fewer ventilators were required than was originally feared and many of these were sourced from existing suppliers or from overseas calling into question the usefulness and cost of the entire programme.

53. Another UK government scheme, 'UK Make', encouraged local manufacturers to re-purpose their operations to produce PPE. By February 2021, volumes produced in the UK surpassed targets in many categories of PPE. However, it is likely that the majority of these manufacturers have now returned to their previous line of business.

Section 6: Supply chains post-pandemic

54. Efforts to improve the resilience of PPE and healthcare equipment supply chains will depend on the successful implementation of a range of measures. Technology will play an important role in creating visibility of stock levels which in turn will improve supply chain managers' decision-making capabilities. New software applications should bring together operational data, including inventory, presently stored in separate systems. Risk management software will provide visibility of upstream supply and mitigate any unexpected events.

55. A diversified supplier base, including UK and overseas manufacturers, will also be important to reduce existing dependencies. It will be essential to develop long term relationships with manufacturers to overcome any potential disruption to supply. Working directly with more manufacturers may have cost implications in terms of procurement and distributors should also remain part of the mix. Healthcare equipment buyers should look at alternative markets to China throughout Asia, North America, Latin America and elsewhere (so-called 'China Plus' strategies) as well as UK domestic and near-sourcing options. A UK manufacturing base may need support in order to be sustainable in the face of low global market prices.

56. Relying on increased stock levels alone is not a 'silver bullet' although the UK and DA governments have increased inventory holdings since the pandemic. Stock needs to be managed to ensure it is fit for purpose and rotated so that it does not go out of date. Entering into agreements with suppliers to hold and rotate stock on behalf of the government is a potential option.

57. The Scottish Government announced a consultation on further centralisation of procurement and distribution, providing a Scottish-led pandemic approach which would cover the entire public sector and not just healthcare providers. Although this might

improve resilience on a national basis, it may also diminish the efficacy of a UK-wide response. The Welsh and Northern Irish DAs have developed plans which aim to improve data sharing; the use of local manufacturing and innovative tendering of contracts, whilst working with the UK government. Improved communication across the Four Nations will be essential in the event of a new pandemic, involving more formal lines of communication; a greater understanding of needs (at hospital, primary and social care levels); a single model of usage; and real time visibility of stock levels.

58. Although, it is to be expected that government policies and guidance on PPE and healthcare equipment usage will change throughout a pandemic, it is critical to take into account the consequences of such changes to supply chains. At the same time, supply chains must be sufficiently resilient to cope with such changes in guidance.

59. New organisational structures will need to be developed by the UK and DA governments which will provide the necessary management capabilities and competence to respond to future pandemics. These will ensure that whilst PPE and healthcare equipment is supplied efficiently during 'business-as-usual' times, the same function will be prepared to deal with a healthcare emergency. Learning from UK and international experiences, this will involve a balance of centralised coordination with devolved decision-making.

60. Supplier relationships will be key to ensuring future resilience. By increasing engagement with suppliers, PPE and healthcare equipment procurement organisations can mitigate the impact of future disruptive events. However, technology platforms should also be utilised to extend the number of suppliers with whom deeper relationships exist, ensuring that more capacity can be tapped by the UK at a time of extreme global demand. This, combined with a UK supply chain ready to step up production at short notice and the other measures recommended throughout the report, will help ensure that the UK is better prepared for any future pandemic.

Section 1: Placing Healthcare Equipment supply chains in context

Section Summary

Supply chains are complex eco-systems of multiple tiers of suppliers, manufacturers, distributors, procurement organisations and end-users. Flows of product to the consumer are facilitated by data, transport, financial, human and energy networks all of which need to function efficiently and effectively to get goods to the right place, at the right time, in the right condition and at the right cost. Mitigation of risk is an increasingly important factor in the design of supply chains and this has led, in recent years, to the adoption of re-shoring, near-sourcing, "China Plus" and other manufacturing strategies. The disruption to supply chains caused by the Covid-19 pandemic, observed not least in the impact to supplies of PPE and other healthcare equipment, has led to a re-appraisal of product costs as the over-riding imperative for procuring organisations. Instead, as discussed in Section 2, resilience of supply has become critical. Re-building a domestic PPE and healthcare equipment manufacturing base, facilitated by automated production processes, will be an essential factor in enhancing such levels of resilience.

How supply chains work

61. The supply of healthcare equipment and specifically Personal Protective Equipment (PPE) to Health and Social Care Workers was a critical issue in the first few months of the Covid-19 pandemic. In order to assess the level of preparedness and the effectiveness of the response by the UK government and other procurement organisations it is first necessary to understand the dynamics of the supply chain and logistics industry. In other words, how supply chains work; why, on occasions, they fail and how they can be made more resilient.

62. According to the Corporate Finance Institute (CFI), the supply chain is an entire system of producing and delivering a product or service, from the very first stage of sourcing the raw materials to the final delivery of the product or service to end-users.

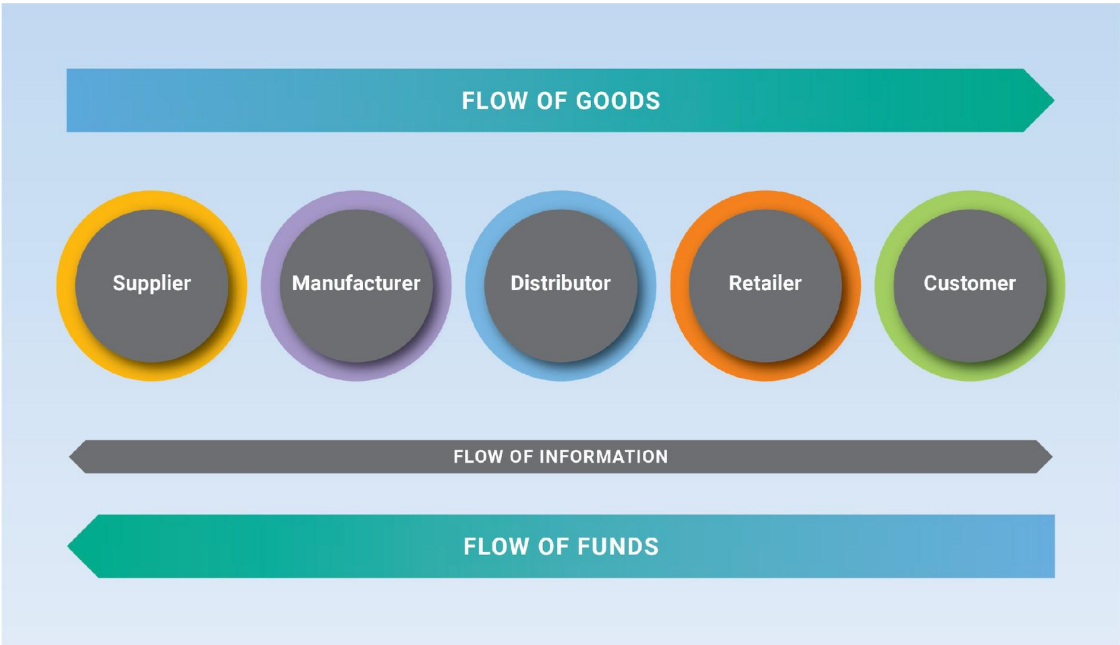
63. Professor Martin Christopher of Cranfield University defines supply chain management as, "The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole". It has also been described by the Council of Supply Chain Management Professionals (CSCMP) as, "Planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption".

64. At the most basic level, a supply chain involves the flow of goods and materials from "upstream" suppliers through a system of "downstream" sub-processors, distributors, manufacturers and retailers, eventually arriving at the customer. At each stage in the process an increasing level of value is added, eventually transforming raw materials into finished products. At the same time as the materials, intermediate goods and finished

products move towards the customer, there are other flows which facilitate the overall process. Information is shared continuously up and down the supply chain, simultaneously providing manufacturers and suppliers with data on customer demand and the customer on when they can expect the goods to be delivered. This allows all parties in the supply chain to better plan production schedules, keep inventory to a minimum and increase efficiency.

65. When a shipment is delivered to a customer, the release of funds is triggered and these flow back upstream. If a cross border shipment is involved, this occurs through a complex system of trade finance involving banks, forwarding agents and shipping lines.

Figure 1: A simple supply chain

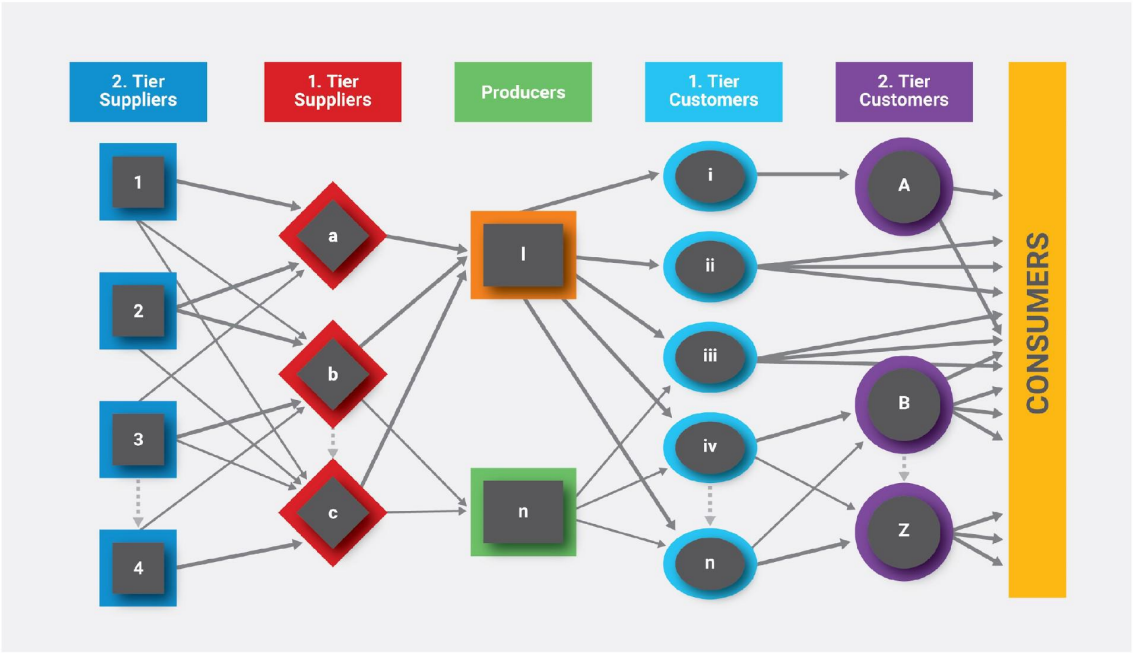


Source: (Author, 2024)

66. In reality, things are much less straightforward. As I will go on to discuss, supply chains are complex networks involving multiple suppliers, distributors and manufacturers often engaged in complex relationships. These can involve collaboration as well as competition. Often the relationships are adversarial resulting from customer-supplier price pressure and this can result in an unwillingness to share commercially sensitive data with other supply chain partners. The consequence of this is that data sits in "silos" compromising the effectiveness of the entire supply chain. To mitigate this lack of visibility, supply chain parties tend to build up unnecessary levels of inventory "just-in-case" it is required to fulfil unexpected demand.

67. As we will see, supply chain complexity and lack of visibility were key factors throughout the Covid-19 pandemic inhibiting the efficient flow of goods and data to healthcare providers and other users.

Figure 2: Complexity of supply chain



Source: (Author, 2024)

68. For the end-user, which in the case of the PPE and other healthcare equipment sector would be a nurse, doctor or other healthcare professional, effective supply chains and their management is not just an academic or commercial issue. If supply chains fail, as they did for multiple reasons during the Covid-19 pandemic, their lives may be at risk.

69. The effectiveness of a supply chain can be measured in terms of its ability to deliver:

- the right products;
- in the right place;
- at the right time;
- in the right condition;
- in the right quality;
- and at the right price (the so-called “6Rs”).

70. Although simplistic, this a good rubric to assess the performance of healthcare equipment supply chains during the pandemic.

71. In commercial supply chains, the most relevant factors causing the inability to fulfil demand include:

- supplier shortages;

- poor demand forecasting;
- late or part deliveries;
- incorrect safety stock levels;
- under-ordering; and
- product quality issues.

Many of these are highly relevant to the supply chain disruption experienced during the Covid-19 pandemic.

72. Modern supply chains are often globalised, integrating the use of remote suppliers based in Asia, most frequently in China. This is especially the case in the healthcare equipment sector. Western manufacturers have been off-shoring production for many decades to take advantage of:

    - lower labour costs; and
    - large and scalable labour forces.

73. The ability to supply markets in the West from production locations in Asia (or elsewhere in the developing world) has been facilitated by low cost and reliable international transport. Since shipping was containerised in the 1950s, it has been possible to move unitised shipments around the world swiftly, efficiently and cheaply. It is often said that the world has become "flattened" not least as barriers to trade have been removed due to the success of the World Trade Organisation (WTO) in reducing and removing tariff and non-tariff barriers.

74. At the same time as this, digitisation has provided better visibility of production and movement of shipments which allows Western manufacturers to adopt "lean" (low) inventory business models by such management techniques as Just-in-Time delivery schedules – delivering goods at exactly the time they are needed in the production process. This means that businesses need to keep less inventory ("stock") in reserve which releases huge financial benefits. Holding more inventory than necessary can result in:

    - capital being tied up which could be better deployed elsewhere;
    - more out-of-date stock;
    - stock being located in the wrong place to meet demand;
    - more lost, damaged or stolen goods; and
    - unnecessary warehousing costs.

75. However, as I will go on to briefly explain, this low inventory business model creates more business risk as if any part of the supply chain and logistics system breaks down, the low level of "buffer" (also known as "safety" or "emergency") stock makes the whole process

vulnerable to disruption. Moreover, the model relies on "right first time" manufacturing: it is critical if products are sub-standard or faulty as they cannot be replaced from stores. This was a major issue for all procurement organisations across the Four Nations during the Covid-19 pandemic, from tearable gloves procured by Shared Services in Wales (AW, 2021) to sub-standard FFP3 facemasks acquired by the DHSC (Kemp, 2021). More details on quality issues are detailed in Section 5.

76. A further important trend has been the centralisation of inventory. This also relates to reduction of stock, a multi-country distribution centre, for example, will store less inventory overall than multiple warehouses supplying national markets. The Single European Market (SEM) which removed barriers to trade throughout the European Union (such as Customs or phytosanitary controls) allowed for the centralisation of distribution, and led to the development of many large, single warehouses in locations in Belgium and Netherlands. This model involves:

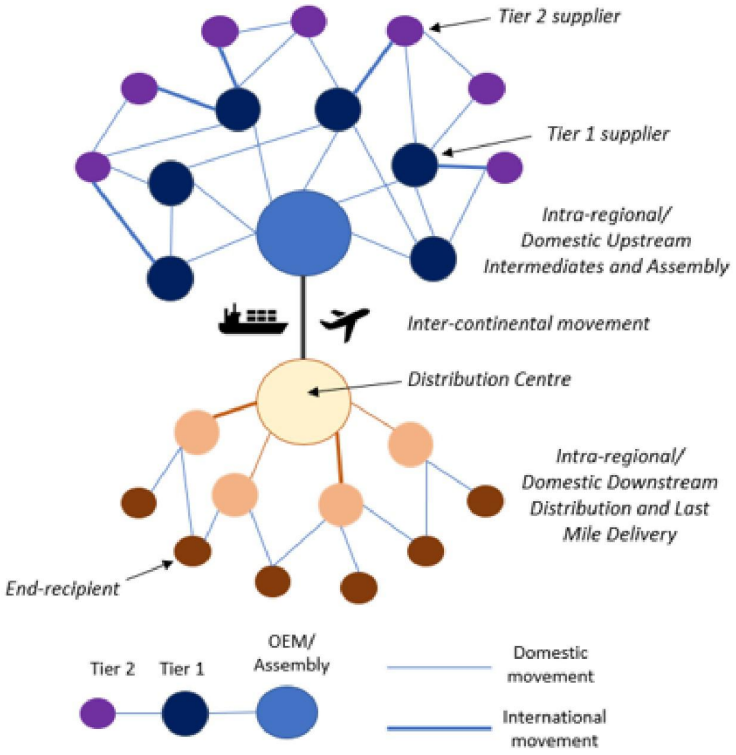
    - the import of goods from Asia through the large ports of Rotterdam and Antwerp;
    - clearance through Customs;
    - storage in facilities in relatively close proximity to these ports; and
    - final distribution throughout the region, predominantly by road.

77. For the UK market, the exit of the UK from the EU has to some extent reversed this trend through the requirement of controls and checks which have been reintroduced at Channel ports. For this reason, it is considered sub-optimal in terms of logistics due to the additional paperwork and delays it has caused, although, during 2020, the UK was still in a transition period from leaving the EU. This meant that CE marked products and those in free circulation in the EU could enter the UK without the "friction" caused by checks.

78. Another feature of modern manufacturing is the advent of "virtual" manufacturing networks. This is very important to the levels of supply chain risk which have developed. The model allows Original Equipment Manufacturers (OEM) to focus on the design and marketing of their products, out-sourcing manufacturing to a small number of "Tier 1" suppliers. These are often based in remote, low cost markets and are responsible for final assembly and delivery of the final product to OEMs' exact specifications. In turn, the "Tier 1" manufacturers will out-source production of components of the product to many more "Tier 2" suppliers who will use "Tier 3" suppliers and so on. In many cases, there will be multiple tiers of suppliers (5 and beyond). This allows each manufacturer to specialise in a particular sector and has largely replaced the "vertical" manufacturing model in which businesses would own and control more stages of the production process.

79. Many parts of the healthcare equipment industry employ virtual manufacturing networks using tiers of providers based in multiple, remote markets as described above.

Figure 3: Global supply chain networks



Source: (Author, 2023)

80. Whilst the "virtual" approach has many cost and business benefits, the most egregious disadvantage is that it creates a high level of supply chain opacity. OEMs may have no idea of the existence of lower tier suppliers – who or where they are, what they produce, their manufacturing, environmental or ethical standards, their production capacity etc. This means that they can also be unaware of risks to production (a comprehensive list of risks is included later in this section) which could disrupt supply and may also lead to unknown risks related to "single" or "sole" sourcing (where a manufacturer may unknowingly be reliant on a single supplier for a critical component).

81. Although out-sourcing of *production* is now commonplace, companies still have moral and legal responsibilities for:

- the impact of their suppliers on the environment;
- the treatment of their suppliers' workers; and
- any damage to societies in which their suppliers operate.

82. This has been codified into UK and European law. During the Covid-19 pandemic, it has been alleged that many governments, including the UK's, believed their primary duty was to supply healthcare equipment and PPE to hospitals and other frontline settings and consequently the impact of supply chains on the environment and on the workers involved

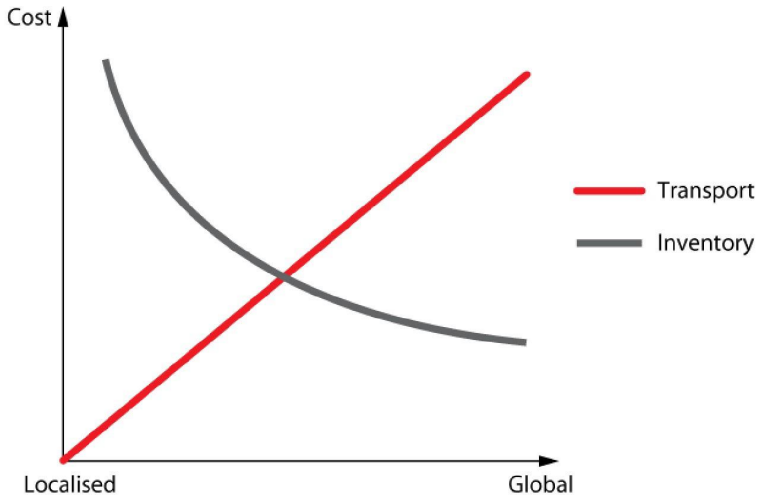
in its manufacture was of secondary importance (Martin-Ortega et al, 2021). This, combined with changing balance of power in the supply chain as huge global demand created a "sellers' market", diminished the ability for buyers to retain their status as "rule setters" in terms of workers' rights and environmental practices. A review undertaken by the DHSC in 2023 stated that, "Modern slavery has many ways of manifesting in PPE supply chains, due to global, complex and opaque supply chains" (DHSC, 2023a). They cited a report undertaken by the Modern Slavery and Human Rights Policy and Evidence Centre into forced labour in the Malaysian medical gloves supply chain. It stated, "Using the ILO's indicators of forced labour as a framework, our research found evidence of all forced labour indicators before and during the Covid-19 pandemic, with evidence that four of the 11 indicators worsened during the pandemic" (MSHR, 2021). The DHSC report also cited a Business and Trade Committee report noting that there were concerns about "reports that the government procured from factories in Xinjiang and other parts of China implicated in modern slavery during the early part of the COVID-19 pandemic" (DHSC, 2023a) However, as "normality" has now returned to the market, and in terms of preparedness for another pandemic, the issue of Modern Slavery should be a factor which is given considerable emphasis. Initiatives undertaken by the DHSC suggest that this is indeed the case.

83. Supply chain strategies have been largely influenced by the trade-off between the cost of moving goods to market and the cost of holding inventories. The relatively cheap cost of transport has allowed manufacturers and retailers to store goods in centralised locations and supply them over longer distances. This has many advantages:

- cost of inventory holding falls;
- less buffer stock is required in each warehouse;
- there is less "shrinkage" ie loss of stock through theft or damage;
- lower levels of redundancy occur; and
- warehouse costs are lower.

84. Figure 4 shows that when goods are stored in close proximity to the end market (e.g. in local warehouses), transport costs are low. If a regional, national or international distribution strategy is implemented, the number of local warehouses falls and so do stock levels. However, transport costs rise, due to the increasing distance to market.

Figure 4: Warehousing and transport cost trade off curve



Source: (Author, 2018)

85. One way in which supply chains can be compromised is through an observed phenomenon called the "bullwhip effect" (Lee et al, 1997). This was very evident throughout the Covid-19 pandemic, relating directly to the disruption of supply of PPE and other healthcare equipment. It therefore deserves examination.

86. The "bullwhip effect" occurs when unforeseen customer demand oscillates up the supply chain, having a greater impact at every level or tier of supplier. Even a small change in customer behaviour can have a significant impact at lower tiers of suppliers. In the "perfect" supply chain, all parties have access to the same quality and quantity of data which would allow supply to be exactly matched with demand. However, for many reasons, not least the adversarial nature of many supplier/customer relationships, the loss of customer confidentiality and the risk of unfair pricing practices, supply chains are more often than not highly opaque. In consequence, retailers, manufacturers, suppliers and distributors tend to overestimate demand (due to a fear of not being able to fulfil orders) and increase their orders and production accordingly.

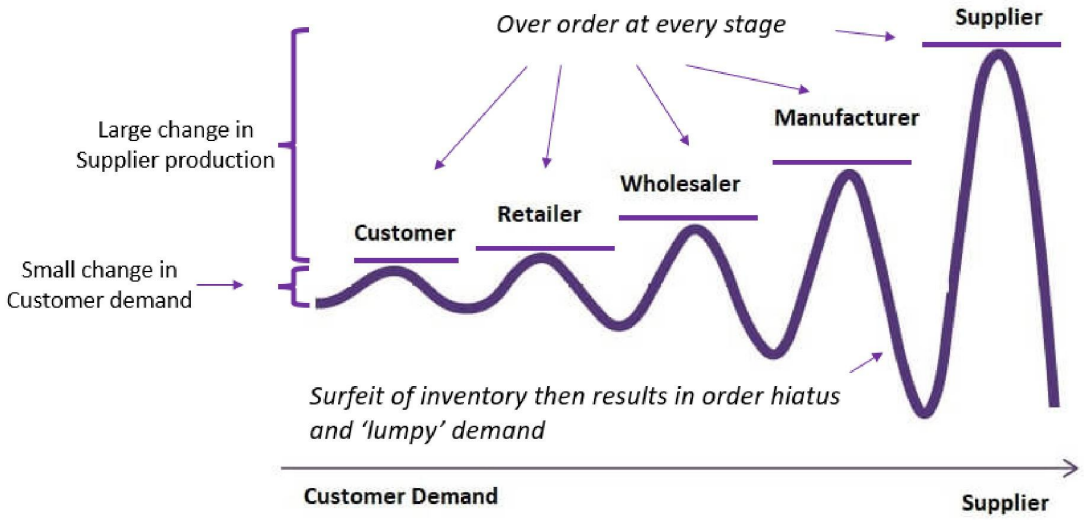
87. Even in normal times this can result in:

- overproduction;
- excess inventory;
- higher transport and warehousing costs;
- longer lead times; and
- boom/bust scenarios resulting in price volatility.

88. The Covid-19 pandemic produced an extreme version of the bullwhip effect which helped to create market dysfunction on a global level. The UK procurement organisations had little visibility of the levels of PPE which were required by local health bodies and other

healthcare providers. As a result, they "pushed" PPE out to the health bodies, estimating their requirements and placing orders with multiple distributors and manufacturers to fulfil future forecasted demand (this will be discussed in detail later in the report).

Figure 5: The "Bull Whip Effect"



Source: (Author, 2024)

89. The procurement organisations had little confidence in any one supplier's ability to fulfil their orders due to the massive global demand (Rajasekharan, 2020). However, by placing multiple orders the situation was made worse, a problem compounded as numerous other countries' healthcare procurement organisations followed the same strategy. Overwhelmed by multiple and inaccurate orders, many contractual relationships broke down resulting in the creation of a "spot market" dominated by buyers with the largest budgets. A 'spot market' is a market in which short term placements of orders are negotiated between buyer and seller at a specific price point reflecting the market conditions of the time.

90. As discussed in more detail throughout the report, the best way to mitigate the "bullwhip effect" is by sharing data throughout the supply chain, whether this is demand, forecast, track and trace or production capacity. Technology will play a major role in these efforts, but the organisational and cultural challenges of building trust between suppliers, customers and other parties must not be under-estimated. Effective data-sharing can only be achieved through stronger, deeper and longer term relationships.

The role of logistics in supply chains

91. Supply chains cannot function without logistics, often described as the "glue" holding together networks of suppliers and manufacturers. The Association of Supply Chain Management defines logistics as, "The process and coordination of products, raw materials, and services across the supply chain. From manufacturing and production to

distribution, fulfilment, and final delivery to customers and end users, logistics is a critical and essential component of a successful supply chain."

Multiple network layers

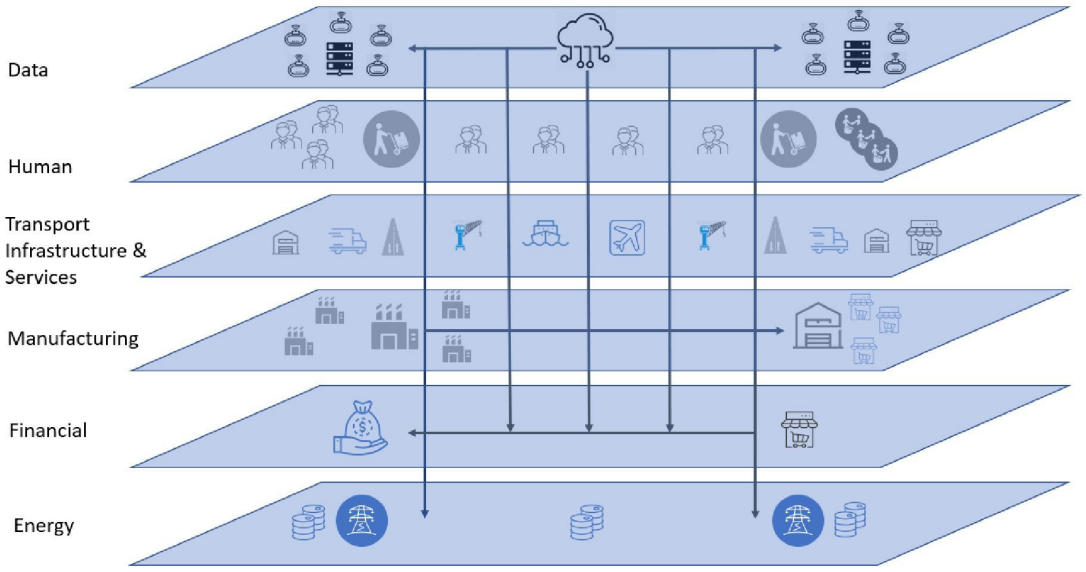
92. Most goods are moved around the world through some form of transport network, whether road, rail, air or sea. Although highly efficient, this means that risk is consolidated at transport nodes ("hubs") such as ports, airports or distribution centres. The lanes ("spokes") connecting these nodes also consolidate risk. An example of this is the on-going disruption to container shipping transiting the Red Sea and Suez Canal.

93. Their very nature means that logistics networks exhibit high levels of fragility. The container shipping sector is probably the standout example. Shipping lines' strategies have been focused on developing economies of scale – reducing cost per shipping container by building ever bigger ships, serving ever fewer trade lanes. The size of the ships has meant that the number of ports at which they can call has reduced.

94. This has resulted in a significant increase in risk, as seen during the Covid-19 pandemic when the West Coast ports of the US were overwhelmed by container volumes. Once one of the main links between the nodes breaks, alternatives for shippers are limited and costs will rise.

95. Logistics is not just about the movement of goods; the fulfilment of a delivery relies on the inter-connection of many different networks. These include information and communications technology (ICT), financial, energy, manufacturing and people, to name a few. The complexity of the relationships between these networks means that it is very difficult to model the impact of a break in any one link, either intra-network or inter-network; a massively complicated 3D paradigm exists.

Figure 6. The inter-relation of networks involved in supply chains



Source: (Author, 2022)

Data Networks

96. Data networks underpin much of the modern supply chain and logistics industry, providing visibility, enabling efficient transport management, GPS data, facilitating communications between shipper, logistics provider, end-user, Customs and border controls to name just a few uses. In addition to this they are essential for air traffic control, traffic management in urban areas and port community systems.

97. With the industry becoming ever more reliant on ICT, any length of downtime becomes critical to efficiency and safety. Just as with human networks, logistics technology is critically vulnerable to the contagion of software viruses. The interconnectedness of global systems has presented an existential threat to even the largest organisations, including the NHS. This shows that whilst the flow of information internally and between companies is necessary to provide visibility (thereby reducing some supply chain risks) too much interconnectedness can result in entire networks being paralysed if a virus is allowed to spread unchecked.

Human networks

98. Until the advent of Covid-19, human networks were rarely analysed in terms of risk to supply chains. However, with the logistics and transport industry being so labour intensive, the human angle has been shown to be a key vulnerability. In fact, there were projects undertaken more than a decade ago to identify the impact of pandemics (avian or swine flu, for example) upon the logistics workforce (McKinnon, 2011). As it turned out, the impact of Covid-19 was less serious than predicted. It had relatively little effect on van and truck drivers, due to the solitary nature of their function. However, warehouse staff were significantly more affected due to the necessary social interaction of their job and the high numbers of people working within a confined space. Warehouse operators implemented Covid-19 protocols to limit the spread of the disease through workforces and automation was introduced.

99. Port operations were amongst the worst affected. In China, the government shut down ports at various times throughout the pandemic under their “zero tolerance” approach to the disease, delaying shipments of PPE and healthcare equipment. In the US, falling throughput at West Coast ports led to a pile up of containers, blamed in part on Covid-19 sickness related absences.

Transport Networks

100. The term “transport network” can refer to both the physical infrastructure and the flows of traffic across it. It could also be said that there is a further “organisational” element, with some passengers (those not moving by car) and all cargo being managed by service providers (either air, sea, road or rail). This is important from a risk perspective as businesses moving goods and passengers interact more closely with other networks such as ICT in the normal pursuit of their business.

101. The various networks interact with each other at nodes, as in many cases journeys are multi-modal in nature. For example, the commute to work will often involve a journey to a rail station by car, a train journey and perhaps a bus at the destination. Likewise, air cargo is almost always moved to the airport by road.

102. The nodes which are an essential part of passenger and freight movements are by their nature bottlenecks and highly vulnerable. In the shipping sector in particular traffic is becoming increasingly concentrated on a diminishing number of nodes (ports) as already mentioned.

103. This concentration of risk also occurs in some prime locations which have developed a cluster of nodes. In China, the origin of a large proportion of PPE used in the UK, Covid-19 in the workforce and a policy of lockdowns affected multiple ports leading to shipment delays of PPE at various times in the pandemic. In the UK, the ports of Felixstowe, Southampton and London Gateway became highly congested due in part to:

- increased import volumes due to a boom in consumer spending;
- dock worker shortages caused by Covid-19; sickness absence and
- truck driver shortages caused by many foreign drivers returning home and furloughed staff (PFE Express, 2020).

104. This led to long delays. It was reported in November 2020 that the number of shipping containers containing PPE and waiting to be moved from the Port of Felixstowe had reached as many as 11,000 at a time when there were still shortages of PPE throughout the system (Sale, 2020).

Manufacturing networks

105. Manufacturing is often characterised by the geospatial clustering of competing and collaborating businesses specialising in a particular sector, such as technology or fashion. Manufacturing expertise develops over time, as does a skilled workforce and a complementary supplier base feeding leading OEMs. In terms of relevance to the production of PPE and healthcare equipment, many of these clusters have developed in China, leading to a consolidation of supply chain risk even in single provinces or states within the country.

The characteristics of healthcare equipment supply chains

106. In terms of product attributes, the PPE sector shares many attributes with consumer goods sectors whilst the manufacturing of ventilators has certain similarities with the consumer electronics sector.

107. For instance, PPE products are relatively simply manufactured. The lack of complexity and low value add have meant that production cost has become the most important factor. This has led manufacturers to off-shore production to remote, low cost labour markets such as China and ship the products to Western buyers.

108. As demonstrated below in the trade figures provided in Section 3, some European markets, especially those with strong manufacturing sectors, such as Germany, have maintained a domestic PPE production base. To enable this in the face of competition from Asia, processes must be facilitated by automation. According to one German executive, "The [face mask manufacturing] machines are fully automated, with only the loading and unloading carried out manually, which is a key requirement for high labour

cost countries. This allows five production lines to be overseen by a single operator" (Wilson, 2020). Although production in the West is not the norm, this does indicate how it might be possible to reduce dependence on off-shored suppliers of PPE and healthcare equipment.

109. Although there are similarities between PPE and consumer goods in terms of materials and production process, there are also specific and important differences which were highlighted during the Covid-19 pandemic. These include:

- the critical nature of healthcare related equipment and supplies. Disruption to PPE and healthcare equipment supply chains may result in an impact on human health, increasing the importance of operational decisions as well as resilience;
- related to the above, the critical nature of quality control and the point at which testing/examination of product occurs in the supply chain;
- demand uncertainty caused by changing government healthcare policy, market intervention, budgets as well as scientific advice on the use of PPE and healthcare equipment products;
- the engagement and interaction between multiple public and private players in healthcare supply chains. Public organisations' procurement strategies may be driven by political imperatives as opposed to purely commercial supply chains which work to a set of established, predictable market "rules";
- the fragmented and complex (potentially competing) roles of centralised procurement agencies, such as NHS Supply Chain (NHS SC), National Services Scotland (NSS), NHS Shared Services in Wales, Business Services Organisation Procurement and Logistics Service (BSO PaLS) in Northern Ireland, individual NHS Trusts, Health Boards as well as primary and social care providers;
- the lack of visibility regarding end-user demand due to this fragmented procurement and demand structure; and
- the high levels of supply chain complexity caused not least by the prevalence of distributors in the market and the overall fragmentation of supply.

110. Very few other supply chains have come under the intense pressure experienced by PPE and healthcare equipment during the Covid-19 pandemic. For instance, photographs of nurses wearing bin liners instead of gowns went "viral", providing politicians with an imperative to "sort out the problem" at any cost. Unlike any other supply chain (with the possible exception of vaccines, caused by the same pressures), the government's considerable resources were placed behind the drive to supply the levels of healthcare equipment required, including significant budgets, Civil and Diplomatic Service structures and even Ministry of Defence workers.

111. In contrast with PPE, the manufacturing of ventilators, as with many other types of high-tech medical equipment, is characterised by:

- small volumes of high value product;
- rigorous testing and compliance processes;
- production to high standards; and
- the assembly of multiple mechanical and electrical components and sub-assemblies.

112. As is discussed later in this report (the "Ventilator Challenge"), this created a completely different set of problems for manufacturers and procurement organisations involving:

- sourcing electronic and mechanical components from multiple remote markets;
- coordination of the supply of these components in final assembly;
- high levels of quality control; and
- high value warehousing and logistics services.

113. Downstream, that is, the part of the supply chain most closely connected to the end user, the PPE and healthcare equipment sector also has a set of unique characteristics. Hospitals, where most of these products are consumed, additionally act as stock holding locations and healthcare workers (HCWs) are often responsible for internal stock control and re-ordering alongside their main jobs. This model can result in over- or under-stocking, wastage and obsolescence, inappropriate storage facilities and lack of technology (DHL, 2020). On top of this, there has in the past been little visibility of stocks (especially those held on wards), disorganisation and pressure on space (Eleanor Hospital Logistics, 2024).

114. One innovation which has been used in the UK and Europe to overcome these problems is the establishment of off-site Hospital Logistics Centre Consolidation Points which deliver direct to wards on a Just-in-Time basis. The potential benefits of this approach are multiple. Consolidation centres can be used to serve a number of local hospitals providing greater visibility of stock and reducing wastage. The visibility which integrated ICT systems provide can be used to measure costs and consumption at patient or location level, giving management greater insight into the product demand.

Case Study - Eleanor Logistics

One example of such an off-site consolidation centre model was designed and built, prior to the pandemic, by Eleanor Logistics for a number of Health Trusts in England including Royal Brompton & Harefield and Imperial College Healthcare.

According to the company, the hospitals in the Trusts had suffered from:

- poor service from an off-site warehouse;
- lack of organisation, systems, service visibility and lost inventory;

- lack of inbound receipting controls of 7300 purchase orders a month;
- in excess of 228 “disorganised” hospital wards to service; and
- little or no system communication tools to enhance the end-user experience.

During the Covid-19 pandemic, Eleanor Logistics, in partnership with the Health Trusts, developed and deployed an emergency crisis and support plan for healthcare equipment and PPE including:

- a service support helpdesk;
- dedicated staff resources;
- restocking schedules;
- off-site warehouse provision;
- on-site PPE stores;
- sector-wide transportation; and
- hospital/sector demand reporting.

In addition to Royal Brompton & Harefield and Imperial College Healthcare, the company has maintained a number of off-site warehouses including for Royal Liverpool Hospital and North Bristol NHS Trusts. The logistics company also provides online catalogues, order systems selecting earliest expiry date products (removing legacy or items at risk of obsolescence from the shelves), picks, packs, labels and dispatches to the hospital point of receipt. The process is entirely trackable online. The off-site warehouse receives goods from all suppliers, which, in England, include NHS Supply Chain.

Source: Eleanor Logistics (2024)

115. A further stage in this development will come as consolidation centres are used as “supplier villages” for vendor managed inventory. This could mean that suppliers will own the product until it is moved directly to the ward, once more ensuring that inventory levels are minimised and service optimised. This concept is common in other industry sectors such as retail, electronics and automotive.

The evolution of supply chain practice

116. Over the past few decades, supply chains have changed significantly. In the past they could be characterised as being “Vertically Integrated”, that is, a manufacturer would typically have:
    - in-house and localised production;
    - operations in developed, Western compliance regimes;
    - local supply chains;

- Just-in-Case production strategies;
- higher inventory holdings;
- fragmented stock holdings in multiple countries; and
- shorter distance to the final market.

117. From the 1980s, there was a trend towards off-shored, virtual manufacturing networks which benefit from:

- low cost labour;
- greater production scalability;
- lower inventory holdings; and
- regionally centralised inventory holdings.

118. However, such manufacturing models are vulnerable to:

- less control over quality;
- lower visibility of lower tiered suppliers;
- operating in nascent compliance regimes;
- siloed data holding across multiple external suppliers;
- long distances to market;
- international transactions;
- low levels of buffer stock and increased vulnerability to disruption;
- higher risk to centralised inventory; and
- more environmental and ethical risks.

119. Since the Covid-19 pandemic and the subsequent disruption to international supply chains, there are signs that more companies are adopting a "hybrid" or "Supply Chain 3.0" model (Manners-Bell, 2022). This can involve some level of vertical re-integration, near-sourcing and re-shoring, providing:

- reduced threat of supply chain disruption;
- enhanced quality control;
- a more developed compliance regime;
- better environmental controls;

- more ethical labour standards;
- better logistics efficiency/lower transport costs; and
- enhanced supply chain visibility

120. The new model also involves some of the following sub-trends:

- "China Plus" manufacturing strategies to reduce the risk of sourcing goods solely from China by diversifying supply across multiple markets.
- Supplier Relationship Management (SRM) to develop more collaborative relationships to break down silos of data.
- Fourth Industrial Revolution (4IR) concepts (such as artificial intelligence, robotics, the Internet of Things, 3D printing, nanotechnology and biotechnology), to transform manufacturing technologies and processes. These will allow manufacturers to better match supply with demand as well as meet specific customer needs more accurately.

121. One of these 4IR concepts, 3D Printing (also known as Additive Manufacturing), was investigated as a possible solution to shortages of healthcare equipment and PPE during the Covid-19 pandemic by the US Food & Drug Administration (FDA). Face shields and nasal swabs were amongst the most 3D Printed items in the USA. In total between February and July 2020 estimated production included:

- 38 million face shield parts;
- 12 million nasal swabs;
- 2.5 million ear savers;
- 241,000 mask parts; and
- 116,000 ventilator parts (FDA, 2023).

122. 3D Printing has the potential to transform PPE and healthcare equipment supply chains as, in theory, it will no longer be necessary to source items from low cost manufacturers in China. However, the technology is not yet mature enough to be an immediate solution. The FDA, as referenced above, found that the challenges faced included:

- reluctance to use non-certified equipment in healthcare settings;
- limited 3D Printing capacity and throughput speeds to manufacture high volume goods;
- shortages of 3D Printing materials such as filaments; and
- unwillingness to invest in technologies due to the uncertainty over long term demand, post-pandemic.

123. Supply chain technologies are also facilitating more efficient inventory strategies. For example, greater levels of inventory visibility will allow stock to be held in multiple locations, challenging traditional centralised distribution models. This will have important ramifications for PPE and healthcare supply chains and as such is discussed in more detail later in this report (Section 3).

124. Whilst these trends and innovations have the potential to secure greater levels of supply chain resilience, PPE and other healthcare products have specific characteristics which will make the transition towards the hybrid model outlined above challenging. In the case of PPE, the economics of manufacturing are highly dependent on low cost labour and this has facilitated the establishment of industries throughout Asia which will be difficult to replace or replicate in the UK without investment in automation.

125. Medical examination gloves are a case in point. At the start and throughout the pandemic, Malaysia was the dominant supplier of rubber gloves to the world market. Since Covid-19, there have been efforts to reduce this reliance on Malaysian manufacturers, especially in the USA where $574 million in government support has been extended to increase domestic glove manufacturing capacity (Greenfieldboyce, 2023). Whilst establishing the necessary factories is one challenge, ensuring that the whole supply chain is resilient and self-contained is another. Further investments would be required to develop the production facilities to manufacture the nitrile butadiene rubber (NBR) used to make the gloves. Importing the raw material would still leave the supply chain vulnerable to a combination of market forces and political intervention by foreign governments.

126. The economics of such a re-shoring policy have been made harder by the entry of Chinese manufacturers into the market. Since the Covid-19 pandemic, they have taken an increasing proportion of the world market, undercutting Malaysian competitors. It is estimated that they can produce gloves for $0.02 (Greenfieldboyce, 2023) which will make production in the US (and other Western countries including the UK) difficult without substantial, on-going subsidy and support (such as guaranteed order levels) or other changes to the market, including tender evaluation criteria. Healthcare providers in the US are not required to buy domestically produced gloves and would argue that sourcing from lower cost suppliers would create savings that could be spent on patient care. However, this does mean that in the event of another pandemic, the US will have to rely heavily on stockpiles of foreign-made gloves rather than the ability to scale up domestic capacity.

127. In order to try and create a sustainable market in the face of competition from China and Malaysia, the governments of Canada and Ottawa have not only contributed $72 million to the development of Medicom's medical-grade glove plant in London, Ontario, but have also committed to buy 500 million gloves annually for its healthcare network (Medicom, 2023).

Author recommendation 1

Whilst it is not possible to reproduce the vast PPE and healthcare equipment manufacturing capacity presently based in Asia within the UK, policy focus should be on developing a small, automated and scalable manufacturing capability. This would be deployed to provide enough product to meet UK demand between the depletion of emergency stockpiles at the beginning of a pandemic and the time when the global market

was able to scale up to meet global demand. This recommendation is discussed in much more length below.

The impact of pandemics on healthcare related equipment supply chains

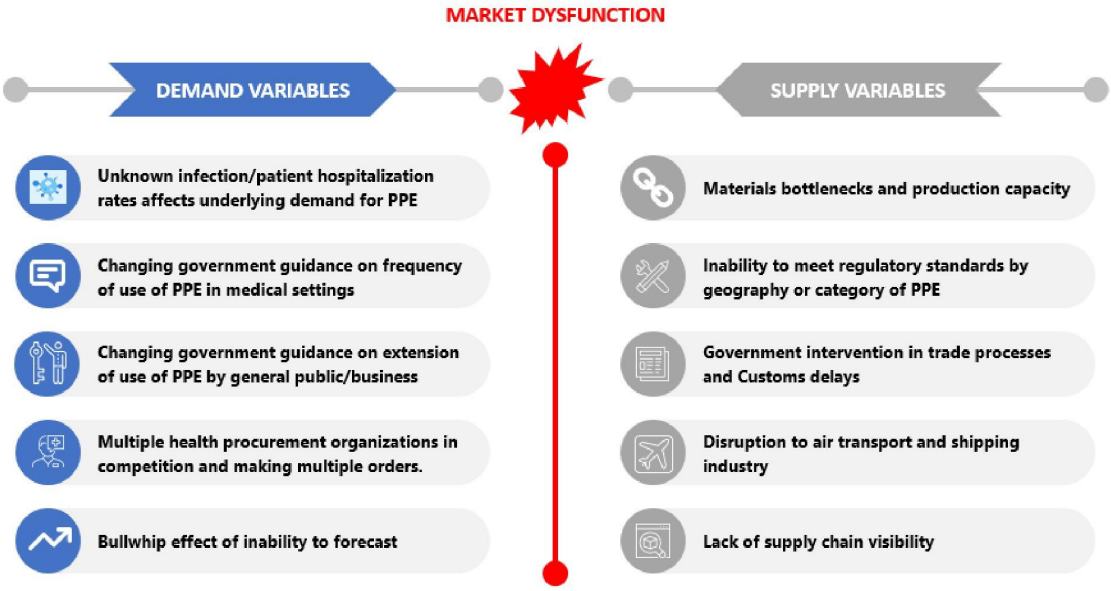
128. Supply chains work best when:

- supply and demand forces are predictable and forecastable;
- the regulatory environment (eg border processes, administration, tariffs and non-tariff barriers etc) remain stable;
- transport and logistics markets are functional;
- trade finance is available;
- currencies are stable;
- geopolitical threats are low; and
- the oil price is stable.

129. Pandemics can disrupt supply chain stability through a range of direct and indirect political, economic and societal effects. For instance, pandemics impact on people's willingness or ability to travel internationally. As a result, airlines reduce the frequency of services and this, in turn, reduces air cargo capacity (most of which is moved in passenger aircraft bellyholds). This was the case in the first few months of the Covid-19 pandemic, leading to disruption to shipments of PPE and other healthcare equipment from China to the West.

130. Figure 7 shows how the volatility in demand and supply variables during Covid-19 created a dysfunctional market.

Figure 7: Volatility in demand and supply variables during Covid created a dysfunctional market



Source: (Author, 2020)

131. The unprecedented circumstances of the pandemic led to wild variability in demand. This was created and exacerbated by an inability to forecast the volumes of PPE and healthcare equipment required, but also the confused and chaotic procurement strategies of individual countries and even hospitals competing against each other or with national agencies. The situation was made worse as countries imposed export bans on many types of PPE and healthcare equipment. Although this came from a political desire to conserve domestic stocks, it resulted in a disjointed and fractured global market and often damaged trust between supplier and customer.

132. As countries attempted to regain some order by centralising purchasing functions, decision-making slowed and bureaucracy increased. Whilst this was an understandable response, it was not necessarily the best solution in a market in which agility and flexibility was critical.

133. The impact of these demand and supply variables and how they can be mitigated by better supply chain resilience is discussed in more detail throughout this paper.

Building supply chains to withstand a healthcare emergency

134. The most important attribute of a well-managed supply chain in an emergency health situation is resiliency. This requires a timely response to any event with the potential to disrupt. The speed of reaction can be described as “agility” – however, it is not enough for just one player in the supply chain to be agile. For a supply chain to continue to function efficiently, it is necessary for multiple parties to have the capability to respond quickly to disruption.

135. Academics, Christopher and Peck, describe “agility” as having two elements: “supply chain visibility” and “supply chain velocity”.

136. Visibility of a supply chain involves a clear understanding of supply and demand (production and purchasing schedules) as well as knowing what inventories are being kept where (Christopher and Peck, 2004). The breakdown of “silos” of data within the supply chain is an important goal to provide these levels of visibility. The flow of data should go both ways: procurement organisations should provide suppliers with demand forecasts and market trends and suppliers should provide data on their own ability to fulfil orders (and that of their own suppliers).

137. Achieving these levels of data-sharing will allow supply chain partners to more accurately identify appropriate levels of stock and enable decision-makers to judge the appropriate trade-off between just-in-case and just-in-time production.

138. “Supply chain velocity” is also critical. How quickly is a product moving in a supply chain and can it be accelerated to respond to a particular disruptive event? Small batch quantities, the choice of transport mode, the reduction of time in which product is held as inventory and streamlining of processes are essential to this concept.

139. Best practice involves:

- enhancing collaboration across supply chain partners;
- building trust-based relationships with suppliers;
- accelerating time to market of new products;
- improving product quality;
- lowering costs; and
- reducing risk and managing crises more effectively.

Case study - Cisco Systems Inc.

A good example of best practice from the high tech sector (and very applicable to an emergency healthcare situation) involves global electronics manufacturer, Cisco Systems Inc.

To obtain information about potential crises, Cisco uses a third-party service that specialises in collecting and correlating events from around the world which could affect its supply chain. An internal team manages this information and, when a crisis event is triggered, the team sends notifications to all relevant parties. At this point, all potentially affected parties are brought together to determine the actual effect and next steps for the situation using a variety of conferencing and collaboration methods. The team then moves on to management and resolution of the crisis using a centralised Risk Management Practice Dashboard.

This application provides an online dashboard that team members can access to view incidents and potential incidents anywhere in the world and coordinate a response. It extends these efforts from intra-company to inter-company, including supply chain partners and logistics companies. The system correlates information about all Cisco suppliers, manufacturing partners and logistics providers with maps and real-time information. Crisis response team members can log onto the dashboard and see where the problem is occurring and how serious the risk may be. The team then takes appropriate actions. After the crisis is over, Cisco undertakes a post-mortem to determine what worked, what requires improvement, and what the early signs of the crisis were.

140. A single plan or playbook on its own is not enough to create a resilient supply chain as, as was evident during the Covid pandemic, plans need to evolve in light of changing events and new information. As former UK civil servant, David Omand, explains in, “How to Survive a Crisis”, it is not that planning is a waste of time, it is that a single plan cannot be flexible enough to deal with every circumstance which may arise (Omand, 2024). Therefore, an effective response should involve a series of plans executed by a team well prepared mentally for unexpected eventualities. The planning process will also involve interactions between all the stakeholders involved in responding to the crisis. It is these relationships which will be crucial rather than the detail of an actual plan which will necessarily have to be flexed as the crisis plays out.

Section 2: Risk and resilience of healthcare and related equipment supply chains

Section Summary

PPE and Healthcare Equipment supply chains face a range of political, economic, societal, environmental, legal and technological risks, heightened by the global nature of virtual manufacturing and sourcing networks. These risks can be mitigated by adopting "risk-agnostic" best practice. The underlying structures which underpin these types of supply chains made them vulnerable to the changing patterns of demand which occurred during the Covid-19 pandemic: overnight, the dynamics of PPE supply chains transformed from those resembling low value, steady-demand CPG goods to high value, volatile high tech products. This needs to be taken into account by supply chain planners in preparation for future potential pandemics. One way to enhance the resilience of PPE and healthcare equipment supply chains is to increase their circularity, which will have benefits in terms of strategic autonomy as well as reducing environmental impact.

The principles of effective and resilient supply chains

141. "Supply chain risk" can be defined as the potential for harm or compromise that arises from a disruptive event which may materially affect a supply chain organisation's ability to fulfil its customers' needs.

142. "Supply chain risk management" is the function of increasing the "robustness" and "resilience" (defined below) of a supply chain to make it less vulnerable to external and internal events or threats, importantly, without compromising social and environmental obligations.

143. "Robustness" is the ability of a supply chain to resist or avoid disruptive value-destroying change whilst "resilience" is the speed with which a supply chain can return to its previous state after a disruptive event ("bouncebackability"). Both these attributes can be achieved by:

- building strong supplier relationships and supply chain transparency;
- communicating clearly with all supply chain partners;
- diversifying supplier base;
- working collaboratively;
- accurate data and forecasting;
- developing systems to collect, integrate, distribute and analyse data; and
- developing backup plans and playbooks.

144. Referring back to the analysis of supply chains contained in the first section, to summarise, a modern supply possesses the following attributes:

- lean inventory;
- centralised distribution;
- Just-in-Time production and delivery;
- remote production in low cost markets;
- use of developing countries; and
- multiple tiers of suppliers.

145. The problem is that whilst the aim of these innovations has been to reduce labour and inventory costs, they have, unrecognised by many managers, created systemic vulnerability.

146. The industry has already experienced the transformation of supply chains from vertically integrated to "virtual". That is, instead of owning all the processes, manufacturers now orchestrate networks of independent companies facilitated by technology, often on a global basis. In other words, out-sourced and off-shored production has replaced in-house and localised. Whilst this has had many benefits, it has meant that strong oversight of processes and controls has been lost as a result. Manufacturing has moved from a developed compliance regime to countries in which governance can be at an early stage of development, impacting upon labour and environmental standards. High levels of supply chain visibility have also diminished. Lean inventory strategies have resulted in lower financial risk, but as the Covid-19 pandemic showed, a high degree of vulnerability to disruptive events.

147. Rather than a return to the high inventory environment of previous generations, however, a "Supply Chain 3.0" scenario is more probable. One in which vertical re-integration and re-shoring becomes far more prevalent as companies seek to enhance quality, reducing risk by locating production in more developed compliance regimes to improve environmental controls and ethical labour standards. This will also increase logistics efficiency whilst reducing transport costs.

148. Companies are employing "China Plus" strategies to diversify risk across multiple geographies and supply chains risk managers are already far more vigilant at identifying dependencies on single and sole suppliers.

149. However, the physical relocation of production and consequent changing sourcing patterns is just one element of future supply chains. All supply chain parties will focus on enhanced supply chain visibility using advanced technologies, including, for example, Artificial Intelligence (AI) which will be used to analyse the vast amount of data generated by global flows of goods to make more effective decisions.

150. In my opinion, there must also be a cultural shift to enable the breakdown of data silos by the development of more collaborative relationships with suppliers, facilitated by digitalisation. This can involve longer term partnerships with suppliers with similar visions

and shared goals, overcoming more traditional adversarial, transactional relationships where mistrust often leads to an unwillingness to share data.

> Author Recommendation 2
>
> The UK government and DAs should encourage centralised procurement organisations to develop deep, value generative supplier relationships with a small number of key suppliers involving:
>
> - understanding how suppliers work and their capabilities;
> - managing and monitoring these suppliers intensively;
> - insisting on data and forecast sharing; and
> - exchanging market knowledge and strategic direction.
>
> Supply chain managers must adopt best practices already employed in industry to develop relationships in which there are benefits to buyer and supplier in business-as-usual times as well as during crises.

Healthcare equipment risk analysis

151. Each individual industry sector supply chain has its own risk profile depending on, amongst other things: levels of complexity; internationalisation of distribution channels; product attributes; lifecycles, cyclicality and seasonality.

152. PPE and healthcare equipment supply chains, specifically, are vulnerable to disruption during a pandemic as a result of:

    - the volatile nature of global demand;
    - the volatile price of the goods being shipped (despite, in some cases, their low intrinsic value);
    - the globalised and fragmented nature of supply chains resulting in low visibility of inventory and shipments;
    - potential disruption to international transport networks;
    - intervention of foreign governments, preventing exports of PPE and healthcare equipment; and
    - complexity of supply chains, increasing vulnerability to counterfeiting and theft, due to the lower levels of visibility and control.

153. Prior to the Covid-19 pandemic, PPE and many other types of healthcare equipment would have been regarded as low risk, not least because of the low product value. However, during the pandemic the value of PPE and other equipment soared, increasing risk, for instance, from counterfeiting or cargo crime.

154. Not all medical supplies share these characteristics. Oxygen, classed as a dangerous substance, has a completely different risk profile from PPE and its production, movement and storage are covered by numerous rules and regulations, such as in the UK and Europe, The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG) and the European agreement "Accord européen relatif au transport international des marchandises dangereuses par route" 1957 (ADR). Other regulations apply to the movement of dangerous goods by air and sea.

Structural risks impacting healthcare supply chains

155. PPE and healthcare equipment supply chains are vulnerable to many of the same risks which threaten other sectors. Many of these risks became evident throughout the course of the pandemic, making supply even more difficult. Whilst some specific examples are mentioned below, it is important to recognise that, when designed, supply chains need to be "risk-agnostic"; that is, they need to be able to respond to any and all threats.

Economic risk

156. Shipping rates are one example of an economic risk. This was particularly important during the pandemic when air cargo and sea freight rates soared as a result of constraint on capacity and demand pressures.

157. Due to their international nature, PPE and healthcare equipment supply chains are also particularly vulnerable to risks related to the inability of suppliers to access trade finance. Manufacturers based in developing countries were impacted by a more risk-averse lending environment which made it more difficult to scale up production during the pandemic.

Natural Disasters and Climate Change

158. Natural disasters can include earthquakes, hurricanes, floods and other climactic events. In July 2020, disastrous floods affected Wuhan, China, a major manufacturing centre of PPE. Some shipments were delayed by three weeks as the Yangtze River burst its banks making shipping impossible (Van Dam, 2020).

Geopolitics/domestic unrest

159. The tensions in the Middle East have disrupted shipping lanes linking Asia with Europe and resulted in container shipping lines taking alternative routes around the Red Sea and Suez Canal. However, of most concern to Western politicians is the potential for a global conflict if China should invade Taiwan. This could have severe consequences for the supply of goods (including PPE and healthcare equipment) to the West from China (Wintour, 2023).

Corruption

160. International supply chains, particularly those which involve developing countries, can be affected by corruption. As one US commentator remarked about trade in PPE, "As companies face intense pressure to quickly obtain goods and clear them through the Customs process to mitigate the healthcare and economic consequences posed by

Covid-19, the risk of [US] Foreign Corrupt Practices Act (FCPA) violations runs high" (Roybal, 2020). The same goes for UK importers under the Bribery Act 2010.

Trade Barriers and Export Controls

161. This involves the disruption which can be caused by controls on international trade, trade wars, regulations and bureaucracy. Trade measures were taken by many countries (including France, Germany and China) to restrict exports of PPE and healthcare equipment at the height of the crisis. As the Federation of German Industries commented, "The restrictions mostly target personal protective equipment such as masks, gloves, and protective clothing, as well as production inputs for medicines…Since production processes are deeply integrated into global value chains, the results of these restrictions are the opposite of what was intended: Export restrictions fuel PPE shortages." (BDI, 2020).

Cargo Crime

162. The heightened prices and shortages of PPE meant that cargo crime became a critical issue for procuring organisations as well as the companies involved in its transportation during the Covid-19 crisis. The Transported Asset Protection Association (TAPA) reported that, "The supply and demand nature of the black market for stolen goods prompted a noticeable spate of thefts of PPE equipment, as offenders looked to cash in on one of the most sought-after products to help fight the outbreak of the coronavirus" (Lennane, 2020)

Ethical and Societal Risks

163. Employee conditions in developing markets are a growing political and legal priority. The exceptional pressure placed on suppliers by procuring organisations and governments to produce more PPE meant that ethical considerations related to workforces were often given a lower priority. As one research document put it, "During the initial wave of Covid-19, most governments prioritised the health of certain populations (ie the citizens of buying authorities) at the expense of harming others (ie the workers producing health protective equipment)" (Martin-Ortega et al, 2021).

Counterfeiting

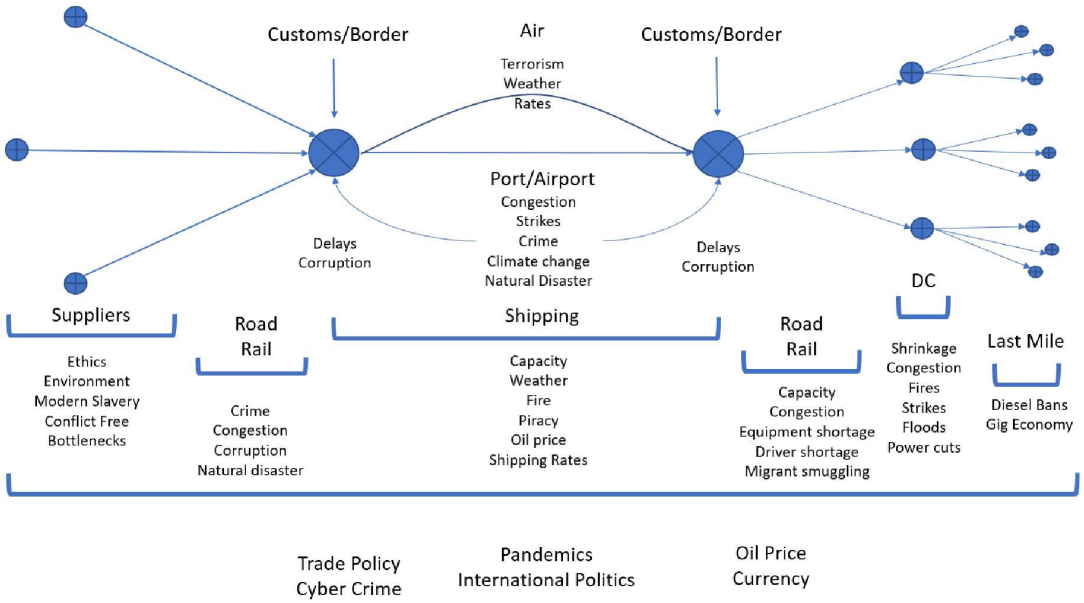
164. The high price and demand for PPE and test kits, as well as lower levels of oversight, meant that the global market became flooded with counterfeit goods. A US Homeland Security Investigation (HSI) noted 668 seizures of counterfeit goods including masks and fake testing devices (EUIPO, 2024).

165. These different types of supply chain risk impact at different parts of the logistics system. For example, ethical concerns are most relevant in emerging markets in the upstream supply chain. The conditions of Uighurs in China, for instance, employed in factories making goods for Western markets. Cargo crime, weather related events, natural disasters and corruption are particularly problematic during transit from warehouse to port in the country of origin, especially in developing countries. At the border, shipments are vulnerable to delays and Customs corruption, whilst air and maritime logistics can be disrupted by terrorism, weather, congestion and strikes not to mention rate volatility. Once

in the downstream distribution system, risks emanate from fire, floods, strikes and power cuts in warehouses, to name but a few.

166. Throughout the entire supply chain there are risks originating from trade wars, the impact of the global price of oil, currency volatility, geo-political risk, cyber crime and, of course, pandemics.

Figure 8: Types of risk occurring at different stages of the supply chain



Source: (Author, 2020)

Author Recommendation 3

Many of the risks involved in sourcing PPE and Healthcare Equipment stem from the globalised nature of virtual manufacturing networks, including the international nature of transportation and lower levels of control and visibility. When awarding contracts, these risks need to be fully identified in order that they can be mitigated. Attempts must be made to cost them into the procurement process. This would "level the playing field" for manufacturers based in the UK where risks to supply are lower, but costs relating to governance, workers, taxation and environmental impact, for example, are higher.

Standards for establishing resilient supply chains

167. Supply chain disruption can occur at many levels – from localised warehouse disruption to regional/global network failure caused perhaps by a major natural disaster. In order to manage and mitigate such wide-ranging threats, businesses are encouraged to adopt a "risk-agnostic" approach formalised through industry standards, such as the standard ISO 31000 (developed by the International Organisation for Standardisation (ISO)). Using this framework can help organisations improve the identification of threats and more effectively allocate and use resources for risk "treatment". They can be utilised to compare

risk management practices with an internationally recognised benchmark, providing the principles of effective management and corporate governance.

168. In addition to the ISO 31000, a further related standard exists, ISO 22301, detailing best practice in business continuity management (BCM). This involves formalising a company's response to extreme weather, fire, flood, natural disaster, theft, IT outage, staff illness or terrorist attack. The ISO 22301 management system identifies threats and the critical business functions they could impact. As with ISO 31000, the standard is what is called "risk-agnostic"; that is, it prepares businesses for all eventualities.

Best practice in supply chain risk management

169. The questions to which any supply chain risk manager needs to know the answers are:

- What can happen and why?
- What are the consequences?
- What is the probability of future occurrence?
- What can mitigate the consequences of risk? and
- What can reduce risk?

170. There are three basic steps that can be taken to prepare for disruption.

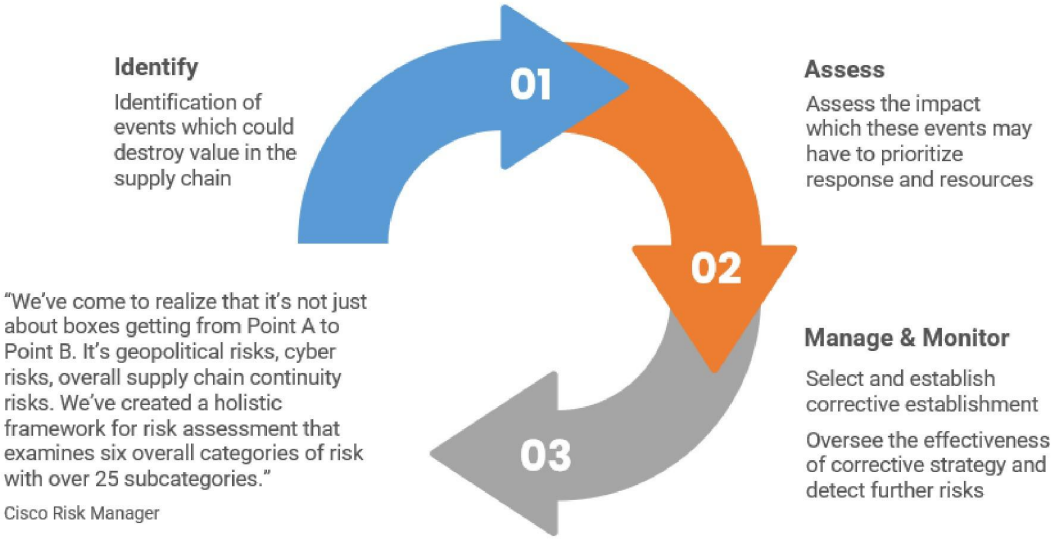
1) Identify events which can destroy value in the supply chain – what are they and where will they occur?
2) Assess – what will their impact be? This helps to prioritise response.
3) Manage and Monitor – select your corrective response, oversee its effectiveness, detect further risks.

171. The first step for any supply chain risk manager is to map the "value chains" of all major products. This will provide an understanding of the stages at which value is added throughout a product's manufacture. Following a review of internal and external manufacturing resources, a risk assessment can be undertaken, identifying the known risks, reviewing "grey" risks – those that are hard to understand or define (e.g. tiers of the supply chain where no visibility exists) - and attempting to rationalise unknown and unknowable risks.

Figure 9. Mapping the supply chain

Source: Author, 2022

Figure 10. Process stages of risk mitigation



Source: (Author, 2022)

172. From this exercise a Risk Register can be created consisting of:

    a. Risks

    b. Potential causes

    c. Consequences – financial, operational, reputational, environmental, societal

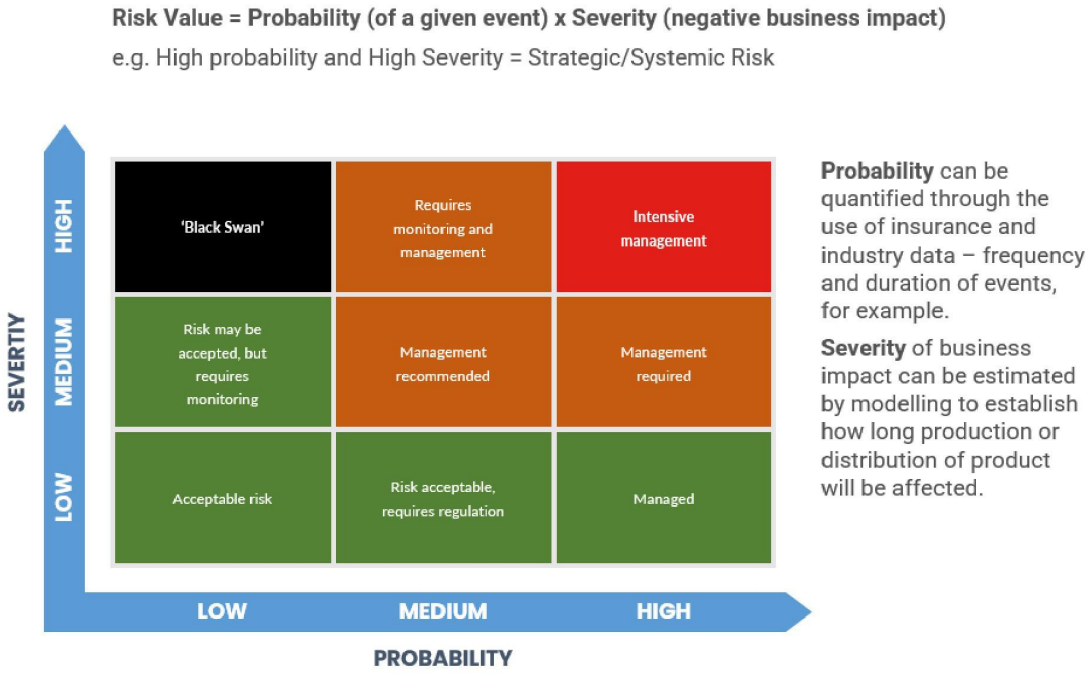
    d. "Treatments" – approach to mitigation

    e. "Ownership" – who within the organisation is responsible for mitigating their effects.

173. One of the key challenges faced by managers is the prioritisation of risk. One simple way is to quantify the potential level of disruption by taking into account the probability of a

given event and its severity. So, if a risk has high probability and it has a high severity then there is a very considerable strategic or systemic risk to the supply chain (top right hand corner). The matrix (Figure 11) suggests that these types of risk should be intensively managed. In the bottom left hand corner are risks which require less management attention – they could be managed as part of normal operations, for example, traffic congestion or warehouse staff sickness.

Figure 11. Risk evaluation matrix



Source: Author, 2022

174. Probability can be quantified through the use of insurance and industry data, for example the frequency and duration of events. The severity of business impact can be modelled using software which establishes how long production or distribution of product will be affected.

175. The matrix also indicates what has come to be known as the "Black Swan" category of disruptive events (top left hand corner). These are "high impact low probability" events (HILPs) which cannot be foreseen, but, when they occur, change the whole understanding of the market.

176. There is disagreement over whether the Covid-19 pandemic should be considered as a "Black Swan" event, as global health emergencies have occurred regularly in the past although obviously not on such a scale (at least not for many years). Based on previous pandemic scares the UK government developed contingency plans which were used in the response to Covid-19. However, for reasons discussed below, these plans did not result in a sufficiently robust PPE and healthcare equipment supply chain.

177. Having undertaken this assessment exercise, managers will be better able to set inventory holdings at a level which will minimise supply chain disruption. However, this

approach is not without its problems. Increasing inventory involves increasing short term costs, goes against established supply chain thinking and is unpopular with managers tasked with delivering value to stakeholders. In the case of PPE and healthcare equipment, these costs are most likely to be borne by procurement organisations and ultimately will be paid for out of healthcare budgets. In fact, this tension between short term cost savings versus longer term supply chain resilience, characterises the debate over the UK's preparedness for the Covid-19 pandemic, as discussed throughout this report.

178. There are other options, of which increasing inventory is just one. Best practice in the industry involves a "risk-neutral" or "risk-agnostic" supply chain risk management strategy – that is, one designed to mitigate the impact of any disruptive event. In addition to the steps already outlined above, this can be achieved by:

    - strengthening leadership to ensure appropriate resources are provided, policies put in place and key people appointed to oversee the implementation of the strategy;
    - planning and setting clear objectives;
    - creating competence enabling a better response to events when they occur; and
    - undertaking business impact analysis, including steps to avoid the occurrence of disruptive events as well as mitigating their impact.

Vulnerability of healthcare equipment supply chains prior to the pandemic

179. The risks of disruption to PPE and other healthcare equipment supply chains from a major health emergency had been identified before the Covid-19 pandemic.

180. The fear that supplies could be disrupted had prompted the UK government to put in place measures that it considered sufficient to deal with a surge in demand and problems with supply. Its strategy, based on reviews of preparedness to previous major health scares (DH, 2011) (DH, 2012) and cross-government exercises (UK and Scottish) consisted of establishing:

    - Stockpiles of PPE and healthcare equipment; and
    - JIT manufacturing contracts with suppliers.

181. Module 1 of the UK Covid-19 Inquiry found that, "The importance of PPE was an issue that arose repeatedly in the exercises" (UK Covid-19 Inquiry, 2024). These exercises included "Alice" (2016, undertaken by the UK government in response to the threat of MERS); "Iris" (2016, undertaken by the Scottish Government in response to the threat of MERS) and "Cygnus" (2016, undertaken by the UK and DA governments, testing the response to a serious influenza pandemic).

182. As it turned out, the steps which were taken were not sufficient to deal with the magnitude of the disruption caused to PPE and healthcare supply chains by the Covid-19 pandemic. As Module 1 of the UK Covid-19 Inquiry also concluded, there was, "insufficient

connection between the assessment of risk and the strategy and plan for dealing with it" (UK Covid-19 Inquiry, 2024).

183. Specifically, the PPE and healthcare equipment strategy that was in place at the outset of the pandemic had been designed to cope with an influenza epidemic (the Pandemic Influenza Preparedness Programme (PIPP) stockpile) as well as the potential for a no-deal EU exit. As discussed in more detail below, it was not effective in dealing with the global Covid-19 pandemic.

184. Referring to the matrix contained in Figure 11, it seems as if the UK government had assessed the probability of a pandemic as a "medium risk" and the severity to PPE and healthcare equipment supply chains as also "medium". If the severity had been assessed as "high" (albeit we only now know how severe), a higher level of preparedness could have been achieved. The UK's preparedness is analysed at length in Section 4.

The development and structure of supply chains and the role of domestic and international manufacturing

185. As part of taking a holistic approach to analysing the response to shortages of PPE and other healthcare equipment as well as determining how such supply chains can be made more resilient in the future, it is useful to look in more detail at how the broader manufacturing industry has developed.

186. During the 1980s and 1990s, Japanese manufacturing processes were adopted throughout the world – the best known of these originated from automotive manufacturer, Toyota. Smaller production runs were adopted with production lines running on an "as and when" required basis depending on demand – the "kanban" system. This Build-to-Order (BTO) strategy did away, in theory, with the need for buffer stocks. Along with a change in production systems, there was also the consequent introduction of Just-in-Time (JIT) delivery schedules which complemented the on-demand nature of manufacturing.

187. As an illustration, if the equivalent model existed in the healthcare sector, every time a box of PPE was emptied in a ward, a "pull signal" would be sent up the supply chain, resulting in a new box being ordered, supplied from stock and a replacement automatically manufactured. This contrasts with the "push" of products down the supply chain (a system employed at the outset of the pandemic) based on modelling or forecasts which may or may not be accurate.

188. The out-sourcing of business functions by manufacturers and retailers over the past thirty years has been another of the defining trends of the industry. Classical out-sourcing theory suggests that companies should identify those functions which are non-essential to its operation and then identify suppliers to take on those activities. This provides a range of cost-saving benefits for the supply chain as a whole, as the supplier can make use of economies of scale to provide a single product more efficiently to a range of customers. Out-sourcing peripheral roles would also have the benefit of taking staff and assets off the manufacturer's balance sheet.

189. Many "manufacturers" are not now actually involved in the production of their goods, instead out-sourcing to Contract Manufacturers (especially in the high tech sector) which

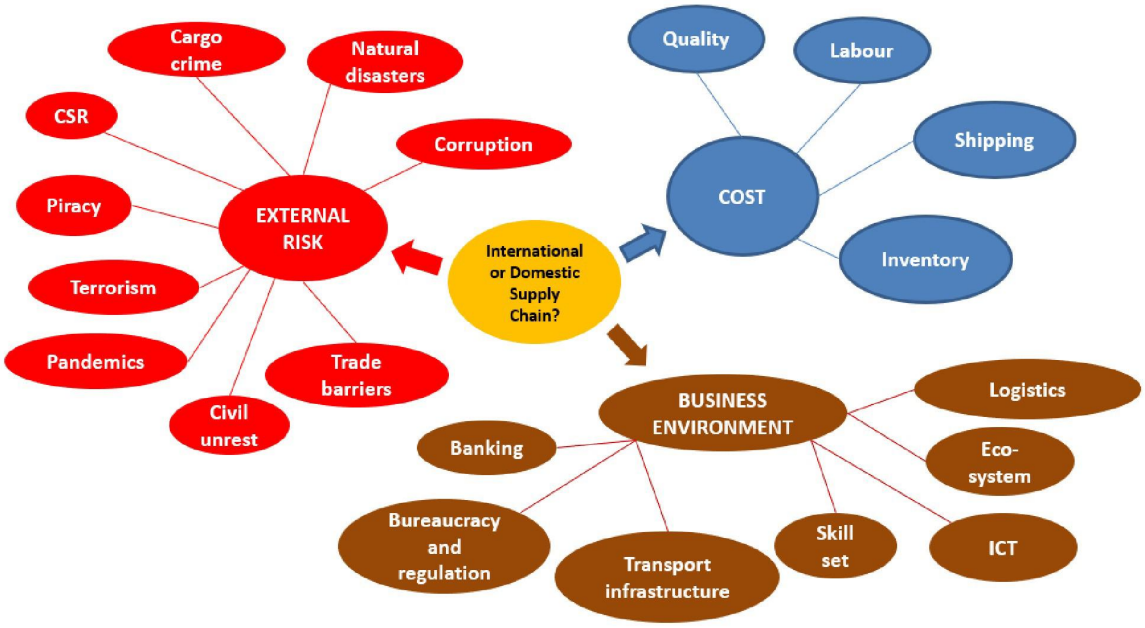
in turn use "tiers" of suppliers, as already discussed. The "Original Equipment Manufacturer" (OEM) focuses on the design and marketing of its products relying on suppliers to maintain flows of materials and finished goods. Quality control is also critical and requires a very active management role. This latter point, as well as being very important to healthcare equipment during the pandemic, is evident across all industry sectors, not least aerospace. Failings in quality management have led to high profile incidents such as the "blow out" of part of a fuselage manufactured by supplier Spirit for Boeing in 2024 (Insinna et al, 2024).

190. The last three decades have seen the out-sourcing and off-shoring of production processes across many markets. The trend was initially observed in Europe with the accession of Spain and Portugal to the European Union and continued with its expansion into Central and Eastern Europe. In North America, the establishment of "maquiladoras" (low cost foreign owned factories) just across the US/Mexico border had the same effect. The facilitation of longer distance supply chains was helped by the development of information and communications technology (ICT) which occurred at the same time as falling transport costs. In Asia, "unbundling" of manufacturing processes has been encouraged by the huge disparity in wage costs compared to physical distances leading to the creation of "Factory Asia". For example, wage costs in China are far lower than those in neighbouring Japan and those in Vietnam cheaper again than those in China, promoting the sub-contracting of production throughout the region.

191. Rising international shipping costs can diminish the benefits of off-shoring production, depending on the goods being manufactured. Shipping price volatility (as seen throughout the Covid-19 pandemic) inevitably influences management decisions, demonstrating the fluidity of the environment in which these decisions are taken.

192. Figure 12 shows the factors involved in deciding whether to use an international or domestic supply chain. It presupposes that a domestic alternative to international suppliers exists. Given that there have been generations of off-shoring of production to remote suppliers, this is often not the case.

Figure 12: Risk factors involved using international or domestic supply chains



Source: (Author, 2024)

193. Primary considerations as to whether to out-source/off-shore production are often related to cost; directly through the cost of labour, inventory and shipping or indirectly, such as through the consequential cost of poor quality products or processes.

194. Secondary considerations relate to the quality of services and systems which exist in the potential off-shoring market. This includes the ease of doing business (including bureaucracy and regulation); the level of development of the banking sector; the skill set of the labour force in that market; the strength of transport and information and communications technology systems as well as the development of the logistics sector.

195. Often of tertiary concern are the levels of external risk which exist, both within the off-shoring market and the international logistics systems which link production and consumer markets. These include factors such as cargo crime, piracy and terrorism; the impact of epidemics and pandemics; natural disasters and weather-related events and the reputational damage related to environment and ethical malpractice.

196. All these factors have to be taken into account by supply chain managers. Domestic supply chains often perform well against metrics which measure the robustness of the business environment and external risk. However, they are often uncompetitive in terms of labour, a cost which can be easily quantified, unlike many of the other factors highlighted above.

197. These factors are of critical importance to understanding the dynamics of the PPE and healthcare equipment sectors. Manufacturing of these products is heavily labour intensive. Access to low cost labour forces in Asia, often in close proximity to the raw materials used in the manufacturing process, have outweighed many of the other highlighted factors.

198. Over the years, a significant proportion of Western manufacturing at the lower value adding end of the market has been off-shored, a process which will take many years to reverse, if indeed this is possible. This must be taken into account when examining the possibility of re-developing a UK PPE and healthcare equipment manufacturing sector as part of a long term supply chain resilience strategy. It will require a determined effort by the government to develop an advanced, automated manufacturing capability less dependent on low labour costs.

International comparisons in terms of healthcare equipment supply chain structure

199. Prior to the Covid-19 pandemic there were very few differences between Western countries in the way that PPE and healthcare equipment supply chains were structured.

200. "Business as usual" supply chains relied on sourcing from global markets, predominantly supplied by Chinese manufacturers. This level of dependence on a single, international market, with all the risks already highlighted, was one of the most important reasons for the market dysfunction which resulted during the pandemic As the Asia Development Bank concluded, "Abrupt, large supply disruptions from the People's Republic of China, as the major supplier of the trade network, will have spill over impact throughout the world. Trade restrictions and export bans also exacerbate the stresses in PPE production and supplies" (ADB, 2020)

201. Emergency contingency policies implemented at a governmental level were also very similar. They involved maintaining stockpiles of PPE, largely designed to cope with a future influenza pandemic, and putting in place contracts with manufacturers which would allow for the scaling up of production if required.

202. However, there are key differences "downstream" rather than "upstream", specifically related to the level of centralisation of procurement. In Europe, individual countries have employed a range of differing approaches.

203. For instance, German health authorities have a highly decentralised approach, devolving procurement of PPE to a regional level (Wilson, 2020). During the pandemic, this proved to be ineffective and the federal government stepped in to take over responsibility.

204. Procurement is also devolved in Italy, a structure which also proved ineffective. A lack of coordinated planning and preparedness meant that public health authorities had low PPE stocks at the outset of the pandemic. Coordination of procurement between regional and national authorities, private health companies and local hospitals was poor. According to the World Economic Forum, "Procurement rules and the fragmented control system have encouraged a climate of bureaucratic conformity and mistrust within the public sector, and between authorities and suppliers" (Vecchi and Cusumano, 2020). The authors also commented that domestic production of PPE took two months to scale up and contracts, new or existing, with global manufacturers were ineffective due to the extreme pressure in demand from other countries.

205. On a European basis, many European administrators regarded competition between Member States for PPE as a critical problem which could weaken the Union as a whole (TBIJ, 2020). Consequently, the European Commission initiated attempts to rationalise

and coordinate purchasing at a European level. 100% EU funded, RescEU was established to create a reserve of medical equipment, from PPE to ventilators, vaccines and therapeutics for use in the last resort if a member's own stocks became depleted.

206. In the USA, the procurement process of PPE is confused by the multitude of private health organisations and the role of state and federal buyers. Bidding wars erupted over consignments of PPE with the Federal government often out-bidding local hospitals. The channels used previously to source PPE proved to be so ineffective in the new environment that some hospitals, never before involved in the international procurement business, set up import operations, sending staff to China to check quality and agree deals. Whilst in some cases this was successful (for example, the State Hospital Association of Washington State managed to purchase 350,000 face masks), this approach increased competition and prevented supplies being assured at a Federal level. In this example, the price paid was 3-4 times pre-Covid-19 pandemic market price, but PPE was reportedly changing hands at up to 10 times normal rates (Kaste and Ruwitch, 2020).

207. There were several US procurement organisations operating at a national level which were designed to prevent supply chain dysfunction at the time of a crisis such as that precipitated by Covid-19. However, they seem to have had limited success. According to the American Medical Association, "The Department of Health and Human Services' Strategic National Stockpile was created to solve precisely this problem, but its inventory is not transparent and news reports suggest its supplies are being distributed unevenly or are insufficient to meet demand" (Livingston et al, 2020).

208. In summary, upstream PPE and healthcare equipment supply chain structures are largely the same whichever market is being supplied. Low cost, remote manufacturers, mostly based in China, use international logistics networks to supply procurement organisations in their largest markets in Europe and North America. However, differences are evident in downstream structures. These occur in terms of:

    - fragmentation and coordination in procurement;
    - planning and preparation;
    - supplier relations;
    - stocks held in event of an emergency; and
    - stock visibility.

209. Fragmentation and complexity, without the necessary visibility of inventory, demand and usage rates, led to a confused and inadequate response. "Business as usual" supply chains were not able to cope under extreme pressure, transmitting "whiplash effects" upstream which impacted on an already under-pressure manufacturing sector.

How the dynamics of healthcare equipment supply chains compare with those of other products

Volatility: the importance of underlying demand patterns

210. In order to understand the problems faced in healthcare equipment supply chains during the Covid-19 pandemic, it is useful to compare the sector's characteristics with other industry sectors.

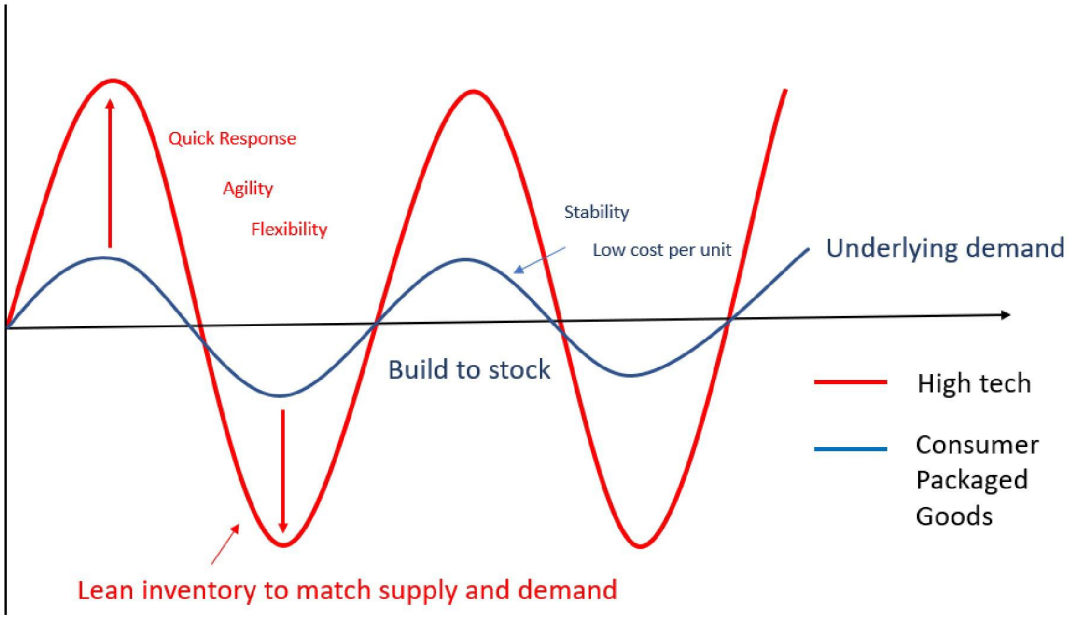
211. Not all supply chains work on a lean inventory, Just-in-Time approach. It makes more sense for a Consumer Packaged Goods (CPG) manufacturer, for example, to work with long production runs based on long term forecasts. As product value is lower, holding more inventory is less problematic than stocking an excess of high value items. This is because CPGs have:

- low demand variability;
- low levels of personalisation;
- economies of scale;
- low manufacturing variability;
- lower lead times; and
- less set up changes of production lines.

212. Prior to the Covid-19 pandemic, the production and supply of PPE and some other healthcare equipment resembled, in many respects, the stability of the CPG supply chain. However, the volatility of demand experienced throughout the crisis more closely resembled an extreme version of the peaks in demand observed in high tech supply chains.

213. To cope with the variability of consumer demand during upturns and downturns, high tech supply chains need to display more agility and scalability than those in the CPG sector, a point illustrated in Figure 13. For instance, suppliers need to have the capability to deploy large, flexible workforces in order to be able to meet product release deadlines. It is not an option to keep large amounts of inventory with the supply chain due to the high value nature of the products and the risk of over-production.

Figure 13. Differences in demand volatility between High Tech and Consumer Packaged Goods



Source: (Author, 2022)

214. One of the key issues impacting PPE and healthcare equipment supply chains was that, almost overnight, they transformed in character from that of CPG to high tech. This meant that stocks diminished very quickly and suppliers did not have the agility to scale up production to meet the demand. It is unlikely that any industry would have been able to cope with such massive and unexpected global demand, but its ability was compromised by the underlying models employed in the sector.

215. One of the problems faced when designing resilient future supply chains for healthcare equipment is the potential volatility in price. In a pandemic, price elasticity is low due to the essential nature of the goods and surging demand can quickly out-strip production capacity (Tang et al, 2022).

216. A supply chain established for low cost healthcare equipment in a "business as usual" environment will be very different from that required by a market which values the products highly during a global pandemic. Manufacturers which operate in developed markets with high labour costs find it difficult to survive when prices for their goods are very low, an economic reality which will always favour low cost, remote competitors. This problem is addressed in more detail in Section 4 and 5.

Author Recommendation 4

Supply chain planners should treat PPE as a high value product, designing resilience through agility, flexibility and velocity. This is despite the low value nature of the

commodity during "business as usual" periods. To ensure that value for money is maintained, smarter solutions and new relationships with suppliers will need to be built.

Transforming PPE from linear to circular supply chains

217. A major trend affecting a wide range of industry sectors is the re-designing of supply chains to be more "circular" rather than "linear". This could have fundamental implications for how healthcare equipment supply chains work in the future.

218. The PPE sector is one of the most egregious examples of a linear supply chain. Products and materials are discarded when their usefulness comes to an end in a process characterised by "take, make, waste". In fact, the sector is fairly unique in that users are mandated by regulations to dispose of certain PPE items, such as masks, aprons and gloves, after a single use (FDA, 2024). One research project concluded that, "PPE reusage practices pose an unacceptably high level of risk of accidental cross-infection contamination to healthcare workers. The current design of PPE requires complete redesign with improved engineering and usability to protect healthcare workers" (Doos et al, 2022). Consequently, whilst efforts are being made to re-use, re-cycle or re-purpose many other types of products, initiatives within the PPE sector are at a very early stage.

219. This presents two major problems: environmental and strategic. It is not in the remit of this report to discuss at length the huge levels of waste which supply chain decisions undeniably caused and its impact on the environment. However, the strategic impact of migrating from linear to circular supply chains could be transformative.

220. Reducing dependence on adversarial countries for supplies of critical goods and materials, such as batteries, rare earth metals and electronic components, is a high political priority in Europe and North America. Over-reliance on China was a crucial reason for the disruption to the supply of PPE and other healthcare equipment in the early days of the pandemic when its government restricted exports (Bown, 2022) and made it easier for Chinese companies to break contracts with foreign suppliers (Bown, 2020a), potentially to focus on domestic needs. Whilst the development of domestic PPE and healthcare equipment industry is one way to increase "strategic autonomy", creating more circularity would also meet this goal.

221. This could be achieved by designing and producing healthcare products which are capable of being re-used. This may involve the use of thicker plastics as well as involve new cleaning processes. One research project conducted at the University of Waterloo, Canada found that the barrier properties of gloves were not affected when they were disinfected between 10 and 20 times (Oosthoek, 2021). Another project at the University of Guelph looked at how fluid-repellent/isolation gowns could be cleaned by ozone treatment, a process already used to clean fruit such as apples and pears (Oosthoek, 2021). Disposable gowns comprise nearly 80% of the isolation gown market (McQuerry et al, 2020).

222. There have been some initiatives in the UK. The DHSC established a Reuse, Innovation and Sustainability (RIS) Team in 2020 with the aim of transitioning HCWs to increased use of reusable PPE products. It has been testing Moist Heat Treatment for some FFP3

masks and the Team works in conjunction with a range of agencies including MHRA and the Surgical Materials Testing Laboratory (DHSC statement, INQ000528391, para 772-774).

223. A private sector initiative, 'Revolution-ZERO', was established in May 2020 and involves the design and manufacture of cotton or polyester drapes and gowns. Their re-use requires a specialised laundry process and sterilisation at 134 degrees Celsius. This has proved a major barrier to adoption by hospitals as much of existing laundry requirements are out-sourced and non-specialist. The organisation plans to build its own cleaning facilities (Henshall, 2023).

224. Introducing even a small element of circularity into the PPE market would have massive implications. However, it will require efforts by a wide range of stakeholders, not least:

- regulators;
- health authorities;
- Healthcare Workers;
- researchers and designers; and
- PPE manufacturers.

225. Against this, there would be cost implications. Such solutions would inevitably be more time consuming and costly than using single use products in a "business as usual" environment. In a price inelastic pandemic market, however, the benefits accruing from the re-use of PPE in terms of cost, supply chain resilience and strategic autonomy would be huge.

Author Recommendation 5

The government should increase investment in research and development related to new, re-usable forms of PPE. This should involve not just trialling the use of new materials but also innovative cleaning technologies. All stakeholders must be involved in this initiative to ensure future industry adoption and create healthcare worker confidence in the migration from single to re-usable products.

Section 3: The structure of the PPE and healthcare equipment industry

Section Summary

PPE and Healthcare Equipment manufacturing has largely been off-shored over the past few decades and the global market is highly dependent on China. This has been identified as a strategic threat to future supplies in a pandemic. It will be difficult to de-couple from China, but not impossible given that sizeable markets still exist in the West as a result of automation.

Mapping supply chains is essential to understand supply chain risk, not just to a Tier 1 level, but upstream to identify the location of raw materials. Downstream, UK PPE and Healthcare Equipment supply chains are very fragmented, especially in England where Health Trusts are able to source their own supplies. Tender evaluation will become an important part of ensuring supply chain resilience by focusing on quality rather than price. Technology will play an increasingly important role in public sector procurement, facilitating data-sharing amongst all partners (as long as trust exists) allowing for better supply chain decision-making.

Market dynamics and structures of the healthcare equipment sector

226. The Global Personal Protective Equipment (PPE) Market has been estimated at $79.5bn in 2023 and is anticipated to grow at approximately 7.2% a year between 2024 and 2030 (Grand View, 2023).

227. The top ten PPE manufacturers in the world have been listed as:

- 3M
- Honeywell
- DuPont
- Ansell
- Moldex
- Uvex
- Kimberly-Clark
- Lakeland Industries
- MSA Safety
- Bullard

228. The PPE market was considered moderately concentrated before the Covid-19 pandemic as a result of the large economies of scale needed to force down production costs per unit in a highly competitive market. As a response to shortages and calls from governments in

the early days of Covid-19, many more companies entered the market, repurposing existing production lines. This resulted in a much higher level of fragmentation for the duration of the pandemic, meeting short term, unfulfilled demand. At the end of the pandemic, the majority of these manufacturers returned to their previous core markets.

229. For the purposes of this report, PPE includes the following categories:

- protective garments (including gowns);
- respirators and surgical masks;
- medical goggles;
- medical shoe covers; and
- hospital gloves.

230. China is the dominant manufacturing centre of PPE. In the year before the Covid-19 pandemic, it was estimated by the International Finance Corporation (IFC) that it accounted for:

- 50-60% of the world's supply of masks;
- 40% of coveralls;
- 40% of aprons;
- 40-50% of eye protection; and
- 30-40% of shoe covers.

231. The only other country to play a major role in PPE and healthcare equipment manufacturing is the US. The IFC estimates that it has a 20-25% market share in these categories (Garcia-Santaolalla et al, 2021).

232. Before the Covid-19 pandemic, China played a smaller role in the manufacture of gloves which were predominantly produced in Malaysia (65%) and Thailand (20%) (Garcia-Santaolalla et al, 2021). These countries have developed a production base close to supplies of raw materials, namely rubber. During and since the pandemic China has aggressively moved into the glove market, competing heavily on price.

233. In Europe, the only significant manufacturers of PPE and healthcare equipment existed in the Czech Republic, France, Germany and Poland. In 2019, the EU imported $17.6 billion worth of these goods and exported $12.1 billion (Poitiers and Brekelmans, 2020). Europe as a market accounted for about a quarter of China's exports of protective garments; a fifth of exports of medical goggles and respirators and surgical masks but only 13% of exports of hospital gloves (Bown, 2020).

234. In summary, the PPE market is highly globalised and heavily reliant on China, with the exception of gloves (a sector in which Malaysian producers have been dominant, although this too is changing). During "business as usual" times this has resulted in economies of scale and cheap supply, but it has also exposed it to a high degree of risk including:

- changes in Chinese government policy and priorities;
- lack of alternative sourcing options; and
- international transport disruption.

235. Moreover, globalisation has also meant that quality control of goods produced in this remote market, particularly critical in this sector, has been difficult to undertake.

236. A brief analysis of the range of products included in each category is essential to understand some of the supply chain pressures experienced throughout the pandemic (See Appendix 1). The more product complexity, range and type involved, the greater the difficulty in ensuring that demand is met consistently. If, for example, there was just one type of surgical gown specified by a procuring organisation, it would be easier to maintain inventory levels and fulfil orders. For each different type of gown specified by a procurement organisation there requires:

- tracking of demand and forecasting;
- specific procurement processes and contracts;
- visibility of inventory turnover rates; and
- establishing appropriate levels of buffer stock.

237. Complexity can result in lower levels of visibility leading to poorer management decisions, inefficient use of existing stock and a requirement for higher levels of inventory to counter this inefficiency.

238. Proliferation of categories within a product type can be driven by, for example:

- technical specification;
- size (eg small, medium, large and extra large);
- material;
- design (eg length of sleeve);
- colour; and
- level of protection.

Levels of single sourcing

239. Single sourcing is defined as buying all of a particular type of product from a single supplier. This is a business choice as buying in bulk can demand better prices as well as reduce the administration and logistics resources required. It should not be confused with "sole sourcing" – a situation which can develop if a supplier is the only source of a particular product in the market. This is an important distinction in terms of risk.

240. Single sourcing is a risk (in the event of disruption) assumed by the customer in order to gain business benefits: there are other suppliers in the market, but the customer decides not to use them.

241. Sole sourcing is a structural risk with potentially more severe consequences. A customer may have become reliant on a supplier which has developed its own unique technologies (a state which exists within the semiconductor industry) or it may have worked with a supplier to develop a unique component design (as frequently occurs within the automotive industry).

242. In terms of PPE and other healthcare equipment, the decision to limit sourcing to a few or even one supplier is a business risk based on a trade off between product cost and supply chain failure. Working with distributors which are able to source from multiple manufacturers should, in theory, mitigate the risk of any single supplier's inability to fulfil orders, whilst providing cost and administration benefits. However, as discussed later in the report, distributors have multiple customers which in times of shortages will compete aggressively on price, meaning that there is no guarantee of supply.

243. Visibility of PPE and healthcare equipment supply chains is often opaque. Many companies not only manufacture their own goods (for example, 3M has 70 production plants), but will also source goods from suppliers. Complicating the situation, they will also source and supply products from other competing manufacturers.

244. Lack of transparency means it is difficult to:

- identify levels of single sourcing and hence risk;
- gauge supply of critical materials involved in the manufacture of PPE; and
- assess risks of modern slavery or environmental practices.

245. As one commentator asserted, "Better end-to-end transparency of the PPE supply chain will allow governments, health care providers and the public to assess the weaknesses of the supply chain and push the manufacturers to fix them" (Dai, 2020). This is an aspiration rather than a reality and will rely on the willingness and the ability of multiple supply chain partners to share production, inventory and logistics data. The inherent complexity and fragmentation of PPE and healthcare equipment supply chains will continue to make this level of data sharing difficult. However, the adoption of new technologies, along with the development of deeper, longer term relationships between purchasers, manufacturers, distributors and their suppliers provides an opportunity to improve supply chain visibility and consequently resilience. The introduction of such a strategy will involve the clear communication by UK and DA governments to procurement organisations of the importance of deeper relationships with suppliers. The inevitable additional short term costs must be regarded as a price worth paying for this enhanced resilience.

The UK's reliance on overseas manufacturing and markets

246. As already mentioned in the first section, the off-shoring of UK production to Asia has been a defining trend of the last few decades. Whilst necessary from a labour cost

perspective, it has also created vulnerabilities which global events have subsequently exposed. A mix of political, societal, environmental, economic and technological factors are challenging the logic of relying on remote suppliers based in adversarial states (such as China) for the supply of critical goods.

247. This has led to calls, in some quarters, for "de-coupling" of supply chains from Chinese suppliers, prompted in part by the disruption to PPE supply during the Covid crisis.

248. As a report published by the Henry Jackson Society asserted, "Although already well-established in the US, the idea of 'decoupling', particularly from China's economy, has gained currency with the Covid-19 crisis. The inability to produce and source Personal Protective Equipment via globalised supply chains has reminded democratic governments and peoples that it is necessary to be able to produce strategic commodities, just as China's actions and behaviour have reminded them of the authoritarian nature of the Chinese Communist Party (CCP)" (Rogers et al, 2020).

249. However, as the report also finds, total economic decoupling in many sectors will be impossible, especially in low value adding, mass manufacturing sectors such as PPE and test devices.

250. Along with many other Western governments, the UK is fully aware of the risks involved in dependence on China. In the wake of the pandemic, it established "Project Defend", an initiative led by the then Department for International Trade (DIT) to identify economic vulnerabilities and critical supply lines. The DIT and consulting company Boston Consulting Group (BCG) produced a report on 22 May 2020 assessing the resilience of 31 supply chains which included 105 action points (Former DIT 1statement, INQ000527714, para 11.21). This project was closed in March 2021 (ibid, para 11.79) but was superseded by a permanent team within the department and augmented by the Cabinet Office Supply Chains Unit, itself absorbed by the Resilience Directorate. However, the UK government's prioritisation of making PPE and healthcare equipment supply chains more resilient remains unclear. In its report, "Critical Imports and Supply Chains Strategy" published in 2024, the sector received only a cursory mention and specific reference to China was absent saying only: "the NHS will implement multiple supplier framework agreements to improve security of supply and to manage demand spikes or individual supplier challenges" (DBT, 2023). Whilst the Scottish and Welsh Governments both aspire to self-sufficiency in some types of PPE (Worthington, 2024), there is no evidence of a strategy formulation process setting out how specific supply chain resilience will be achieved.

<u>UK's dependence on imports of PPE and healthcare equipment</u>

251. Using the World Health Organisation (WHO)/World Customs Organisation (WCO) tariff classification references for Covid-19 medical supplies and the UN Comtrade database, it is possible to assess which countries the UK was most dependent on throughout the pandemic for the supply of PPE and other healthcare equipment.

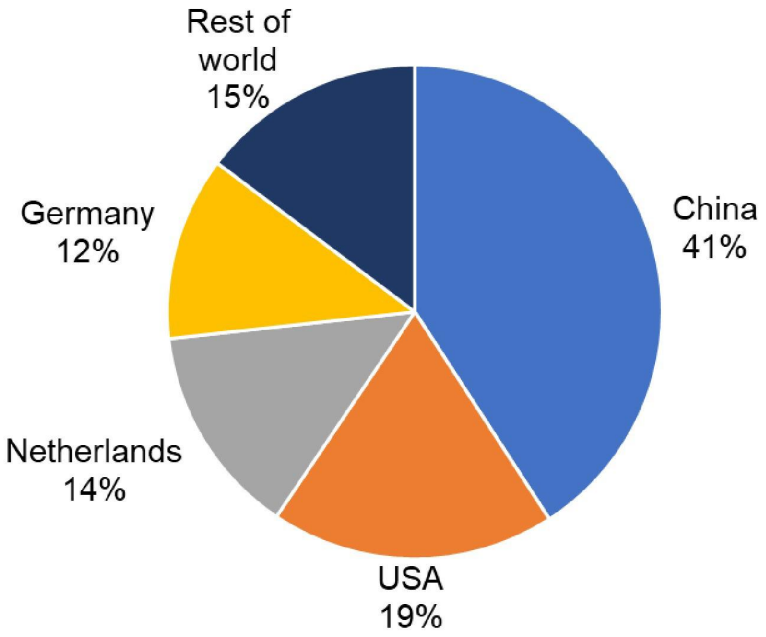
252. The first example is Covid-19 test kits (PCR) under HS code 3822.19. It is evident from Figure 14 that China is the dominant exporter to the UK (2022 figures) accounting for over 41% of imports by value. In fact, (and as with the other examples below) this understates China's position as it does not take into account the "Rotterdam Effect" (Mion and Aznar,

2024). That is, many goods from China are imported through Europe's largest ports (Rotterdam being the most important), stored and then distributed to the UK from central European distribution centres, consequently showing up as being of European origin in the data.

253. In addition to this, China's ability to manufacture tests more cheaply than anywhere else in the world means that in terms of volumes, value figures will also understate its importance. The level of dependence on China is clear.

254. Europe does have some manufacturing capabilities, as can be seen from Germany's 12% share of the UK export market. TIB Molbiol, acquired by pharmaceutical company Roche in 2021, is one such company producing PCR tests in Germany at a 40,000 sqm facility in Berlin. It also has factories based in the USA, Italy, Spain and Colombia, providing an alternative to Chinese suppliers.

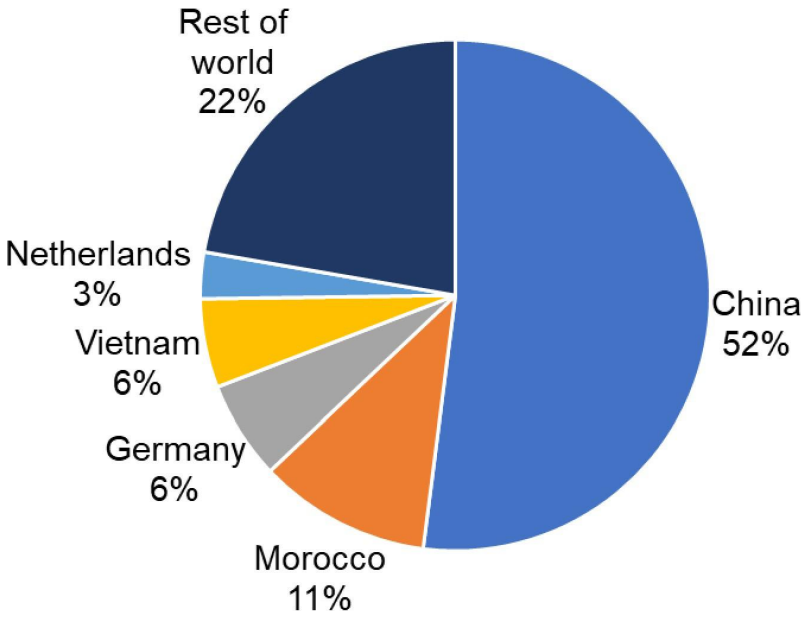
Figure 14. Largest exporters of COVID-19 Test kits to UK (HS 3822.19)



Source: (Comtrade/author, 2024)

255. Face-masks, including surgical masks and disposable face-masks and type N95 Particulate Respirators (HS code 6307.90). As can be seen from Figure 15, China accounts for over half of the market. It is notable that other markets such as Morocco, Vietnam and Turkey, important players in the general textiles manufacturing sector, provide near-sourcing and "China Plus" options for the production of face masks. Outside the top ten, the "rest of the world" has a larger share of the market, indicating higher levels of fragmentation than in the Covid test device market, for example.

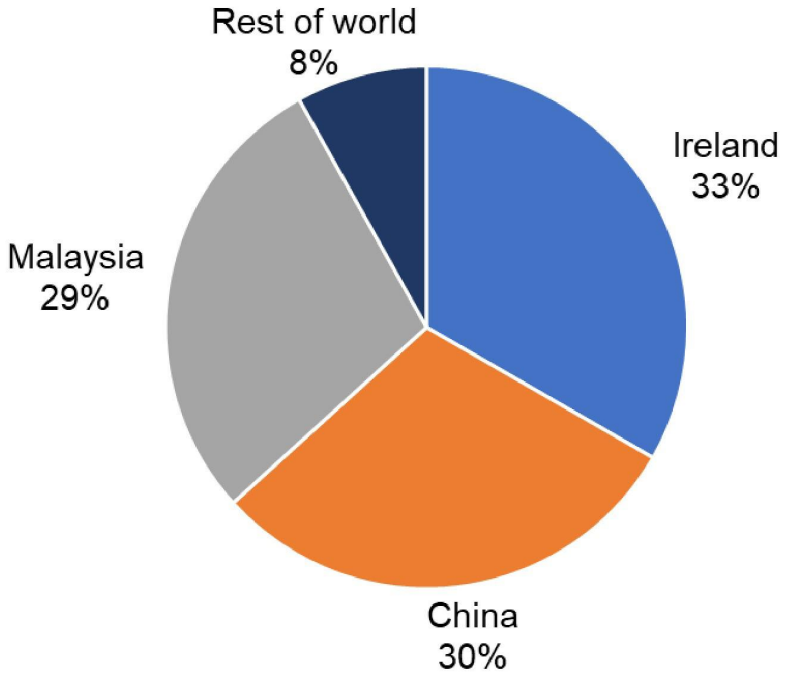
Figure 15. World's largest exporters of Textile Face Masks inc. N95 to UK (HS 6307.90)



Source: (Comtrade/author, 2024)

256. In contrast, the surgical gloves market has a different profile from the two examples above. As can be seen in Figure 16, Ireland is the largest exporter of surgical gloves to the UK (HS code 4015.12). However, this figure is deceptive as major glove distributors are based in Ireland, re-exporting gloves sourced from Malaysia, Thailand and China. In terms of manufacturing, and of more relevance to supply chain resilience, Malaysia, Thailand and China dominate the market. If Ireland's share is re-allocated to these two countries, then between them they have a market share of over 90%.

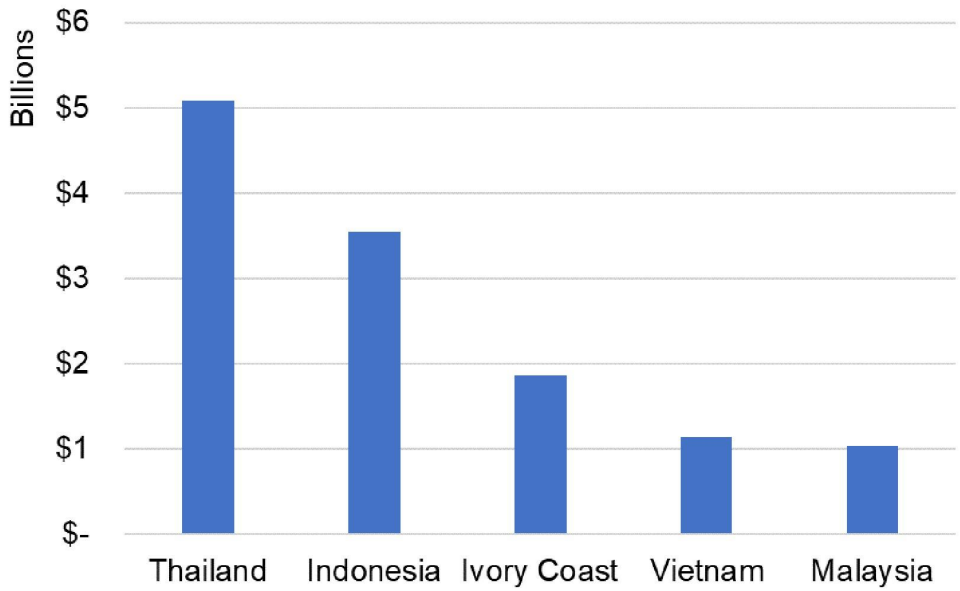
Figure 16. World's largest exporters of surgical gloves to UK (HS 4015.12)



Source: (Comtrade/author, 2024)

257. As an example of how further investigation reveals upstream supply chain vulnerabilities, Figure 17 shows the dependency of the global glove manufacturing market on Thailand, Indonesia and to a lesser extent Ivory Coast. Whilst China and Malaysia have developed large scale glove manufacturing capabilities, both countries rely heavily (China more so) on the import of raw material from other parts of the world.

Figure 17. World's largest exporters of Rubber (HS 4001)



Source: (Comtrade/author, 2024)

258. Produced ultimately from oil, the manufacture of synthetic rubber (which includes nitrile) is less dependent on these rubber producing countries. The top five largest exporters are Korea, Thailand, USA, Japan and Vietnam each with a similar market share. For the production of nitrile gloves, therefore, there are fewer upstream risks, but the risks of concentration of downstream manufacturing in Malaysia and China remain.

259. In conclusion, in order to understand the risks relevant to each type of PPE or healthcare equipment, it is necessary to undertake a detailed examination of the supplier tiers, up to and including raw materials. Doing so exposes concentrations of risk which can include geo-political, environmental, ethical or economic. For example, in recent years rubber production has been hit by floods, drought and disease. Supply of rubber has also been disrupted at various times by a lack of shipping containers which has pushed up prices and delayed shipments. This will impact the supply and prices of gloves.

260. It is noteworthy that whilst China dominates many of the PPE and Healthcare Equipment markets, many other countries do have manufacturing sectors of material size, successfully exporting to the global market despite the low cost nature of some of the products (in "business as usual" times). As already referenced, in Europe, manufacturers achieve this through investment in automation and new technologies, a fact which should not be lost on the UK government.

Downstream PPE and healthcare equipment distribution channels in the UK

261. Downstream distribution of PPE and healthcare equipment is handled very differently across the Four Nations. Understanding the fragmented and complex downstream structures is essential to assessing the preparedness for the pandemic; how well (or not) the system worked and how supply chains can be made more resilient to cope with future healthcare emergencies.

262. In England, distribution is handled by NHS Supply Chain (NHS SC) which supplies a large proportion of the needs of 226 Health Trusts (DHSC, 2020c). As discussed later in the report, NHS SC, was established to act as a centralised procurement organisation as a way of consolidating the NHS's buying power in the global market. However, NHS Trusts were not (and are still not) under any obligation to use NHS SC (SCCL statement, INQ000492085, para 7.4). Consequently, whilst just over half of NHS Trusts' supplies are sourced through NHS SC, they have also established and maintained their own distribution channels with manufacturers, distributors and wholesalers. As SCCL makes clear, ("NHS Supply Chain is not the same as the supply chain for the NHS…it covers only a proportion of the products purchased for the NHS for which a number of other supply chains exist" (SCCL statement, INQ000492085 para 3.3).

263. NHS SC fulfils Trusts' orders in a variety of ways:

- From stock held in one of its national and regional distribution centres within a target time of 48 hours;
- Direct from the supplier to the Trust ("eDirect") with transport organised by the supplier within NHS SC ordering system; and
- Direct from the approved supplier to the Trust ("direct") outside of NHS SC normal ordering system.

264. Whilst the model proved workable during "business as usual" times, it proved inadequate to cope with the pressures placed upon it during the pandemic, both in terms of serving existing customers and to expand its remit to include primary and social care providers (see DHSC 2020c, paras 3.6-3.7). Consequently, by the end of 2020, a new distribution network had been established (the "Parallel Supply Chain") to supply 58,000 different settings (DHSC, 2020a), discussed in more detail below.

265. As well as distribution direct to hospitals, on 4 April 2020 the decision was made by the DHSC to use existing local resilience forums (LRFs) to distribute PPE to other sectors of health and social care (DHSC statement, INQ000528391, para 650). Local authorities started to take over the distribution of PPE from LRFs from 14 September 2020 onwards (ibid., para 656).

266. The PPE programme also enabled care providers such as GP, pharmacies, social care providers and dentists to source PPE free of charge directly from designated wholesalers. Previously, they had been responsible for sourcing their own supplies but this arrangement proved unsustainable due to the disruption to the market (DHSC, 2022c).

267. Whilst NHS SC is very important to the downstream supply chain in England, a large proportion of procurement is still undertaken by NHS Health Trusts, buying for the individual hospitals under their aegis. They have relationships with distributors and manufacturers, their own warehousing consolidation centres and transport operations and, in many cases, their own Inventory Management Systems (IMS). Since July 2022, the Trusts have been grouped with local authorities, voluntary and community organisations, the wider public sector and universities into Integrated Care Systems (ICSs) based on geographic location although it is yet to be seen whether PPE and healthcare equipment procurement will fall within their role and responsibilities.

268. Different arrangements exist in the Devolved Administrations (DAs). In Scotland, NHS Boards (hospitals and community care) are primarily supplied by the national procurement organisation, NHS National Services Scotland (NSS), although they, as in England, have the opportunity to buy their own PPE and healthcare equipment directly from distributors or manufacturers. Local Authorities (LAs), including adult social care provision, either buy their own or use the Scotland Excel framework, a centralised buying organisation established for Scottish local governments.

269. During the pandemic, NSS also took on the role of supporting LAs as well as other public sector providers, such as fire services, and primary care independent contractors working for the NHS.

270. As discussed in more detail below, the Scottish Government is looking at extending the remit of the NSS to become responsible for all public sector buying of PPE and healthcare equipment in Scotland (including for Health Boards and LAs) as well as managing the pandemic stockpile.

271. In Wales, NHS Wales Shared Services Partnership (Shared Services) undertakes a centralised procurement and supply role for healthcare organisations utilising three warehouses across the country. It works on behalf of 7 local Health Boards and 3 NHS Trusts (including the ambulance service). Throughout the pandemic, healthcare providers predominantly used Shared Services as the main supplier of PPE and healthcare equipment, although there were reports that, at the height of the disruption, some providers were forced to make their own arrangements (BBC, 2020b). However, a report by the Wales Audit Office into the supply of PPE found no evidence that national supplies ran out (although it also stated that, "some frontline staff have reported experiencing shortages of PPE") (AW, 2021a). Shared Services also played a role in distributing PPE and healthcare equipment to social care providers, working in conjunction with local government (Welsh Government statement, INQ000506956, para 41).

272. In Northern Ireland, PPE and healthcare equipment is procured by the Business Services Organisation Procurement and Logistics Service (BSO PaLS), an independent body of the Department of Health (DoH) through four fixed price contracts. It supplies six Health and Social Care (HSC) Trusts with over 99% of their requirements, although they also have the right to independently make their own purchases (NIAO, 2022). The Trusts each deliver regional integrated health and social care services across settings which include hospitals, health centres, residential homes and care centres.

The importance of transport and logistics structures to maintain the UK's supply chains

273. The UK is very well integrated into global logistics networks which provides it with a significant advantage over countries which do not have the same level of "connectedness". Not only does it enjoy direct links with a significant number of markets through modern sea ports and airports but air cargo carrier and shipping services are very frequent and have high capacity. It also has a highly developed freight forwarding, express parcels, road freight, shipping and air cargo sector, providing high quality and innovative logistics services.

274. Domestically, the UK has led the world in value adding contract logistics and express parcels solutions. Under intense stress during the early days of the Covid-19 pandemic, the industry was agile enough to cope with the huge demand for groceries caused by panic buying as well as pivot to cater for Working from Home practices.

275. However, the UK's insular geographic characteristics create heightened risk. Whilst network designers are tasked with developing and maintaining systems which facilitate the movement of goods and data as efficiently and quickly as possible, regulators often create "friction" within a network by introducing barriers at international borders. These can include Customs, border controls, trading standards, phytosanitary checks or security screening at airports or ports.

276. The introduction of controls at the UK border after its exit from the EU are examples of such "friction" leading to additional delays and costs (although transitional arrangements were in place throughout 2020). Prior to the Covid-19 pandemic, this resulted in the establishment of a stockpile of PPE to be used in case of disruption caused by a no-deal scenario with the European Union. This was in addition to the existing stockpile created as part of the government's preparedness strategy for an influenza pandemic (Pandemic Influenza Preparedness Plan or PIPP).

The role of procurement strategy and tender evaluation in the resilience of supply chains

277. Procurement strategy plays an important role in increasing the resilience of supply chains. Firstly, it is important to enhance relationships with key suppliers. This involves, on one hand, an openness in data and forecast sharing by customers and, on the other, honesty and transparency on behalf of the supplier. Suppliers must also be mindful of the benefits of long term relationships whilst customers would be advised to look beyond a transactional relationship based on cost.

278. For example, suppliers may be able to build out production capabilities through enhanced investment made possible by long term contracts and greater visibility of future demand. This approach has worked very well in the high tech sector. Consumer electronics manufacturer Apple has worked for many decades with Taiwanese contract manufacturer, Foxconn (also known as Honhai Technologies) (Aristo Sourcing, 2024). The strong, long term relationship has allowed Apple to:

    - scale up production to meet demand when new products are launched (whilst Apple focuses on design and marketing);
    - leverage Foxconn's economies of scale and low labour costs; and
    - benefit from Foxconn's logistics capabilities.

279. The relationship has been based on mutual trust, collaboration and commitment and can be described as synergistic. The Apple/Foxconn relationship is by no means unique. The model is used extensively throughout the consumer electronics sector and there is no reason why certain aspects could not apply to the manufacture of PPE and other healthcare equipment. In this respect it is notable that Apple believes a single sourcing relationship is more advantageous in terms of risk management than having multiple suppliers. A prerequisite of this approach is engagement, trust and visibility. Apple's

buying power is obviously a factor in being able to structure its supply chain – the UK's health providers' spend should also allow them to develop supply chain relationships in a way that will benefit all parties.

280. Running alongside these long term and deep relationships, it is wise that procuring organisations build "tactical" commercial capabilities to tap the open market when product shortages exist from established suppliers. Maintaining product standardisation is important in this regard to ensure that generic products are available from as wide a supplier base as possible. This would mean a reduction in what the Carter review of English hospitals called "unwarranted variations", that is, in this context, ensuring that hospitals (and other organisations) make use of economies of scale and reduce the proliferation of products used (Lord Carter, 2016). The review, at the time, praised other countries' hospital systems which had adopted "core lists", but given the fragmentation of the UK's procurement environment, achieving this goal has been limited to NHS Supply Chain in England only.

281. Whilst running long term partnerships and open market strategies in parallel is only sensible, it often presents the temptation for buyers to switch between the two when prices are low. This will diminish the levels of trust and increase the probability that suppliers will sell to the highest bidder when there are shortages and prices are high.

282. Tender evaluation is an important tool in ensuring supply chain resilience. It is one way in which the customer can assess the supplier's preparedness for a disruptive event by investigating the processes it has in place.

- Does the supplier conform with an international standard of risk planning?
- How financially robust is the company?
- What visibility does it have of its own suppliers?
- Where are these located and what risks do they face?
- How quickly can it detect and respond to a disruptive event?
- What risk mitigation plans are in place?
- What policies does it have as regards modern slavery or environmental practices?
- What visibility and risk management technologies does it operate?

283. Indeed, as the government itself commented, "We will consider how our tendering principles and criteria will need to adapt to deliver our overall approach to resilience, ensuring that the experience and learning gained from the crisis procurement processes are applied in the future, for example short lead times for delivery" (DHSC, 2020c).

284. This presumably means that cost will not be as important a component in the contracting process as before the pandemic. Anecdotally, in an NHS SC Framework contract, price now makes up a weighting of between 40-60% of the decision, and "quality" the remainder. This means that a supplier could win on the basis of a high score on quality and a lower score on price.

285. Quality includes “service and supply” which also involves sustainability, supplier practices, social value and the ability to deliver product to the NHS within 48 hours.

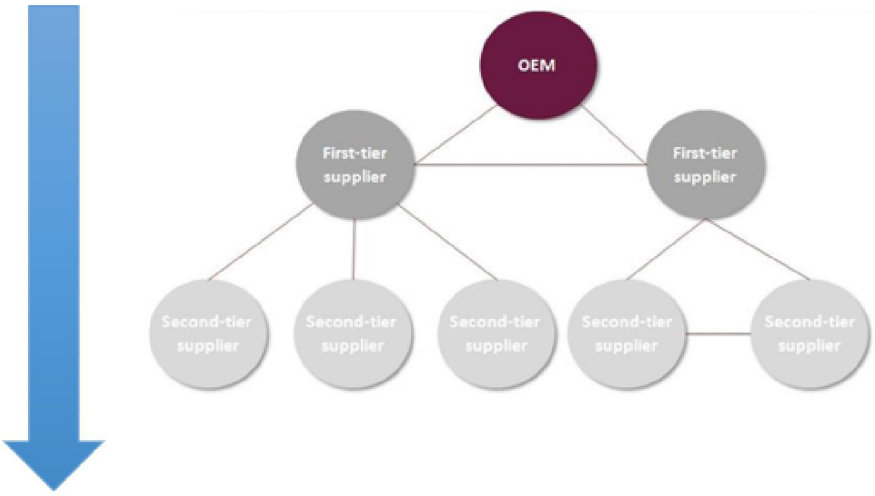
286. However, it may be harder for a supplier to score highly in terms of “quality” than it is on price and this will place low cost, remote suppliers at a competitive advantage. The tender process, the questions asked and the weighting given to the responses is important to consider for resilience in future pandemics.

> Author recommendation 6
>
> There should be clarity on the terms of reference used by healthcare providers when awarding PPE and Healthcare Equipment contracts. Defining “quality” and ensuring decisions are properly weighted to take into account supply chain resilience issues will be essential for pandemic preparedness.

The role of technology in assessing risk and building resilience

287. The complexity of virtual, “tiered” supply chains makes understanding risk difficult due to the lack of visibility caused by the existence of “data silos”.

Figure 18. Visibility in “tiered” supply chains



Source: (Author, 2022)

288. A key step to mitigating risk is better supply chain collaboration between procurement organisations, manufacturers, distributors, suppliers and logistics partners. Technology plays an important role in this, but it also involves moving from purely transactional relationships to engagement based on sharing trust, data, business vision and goals. The

Covid-19 pandemic showed that supply chains based on long term engagement between procurer and supplier were more resilient and reliable than those which were based purely on price.

289. New technologies can result in digitalisation of supply chains creating visibility of:

- customer demand;
- supplier production plans and component availability;
- delivery process; and
- disruptive events.

290. In the modern supply chain, generating data is not a problem. However, analysing the vast amounts of data which are created by widely available, low cost sensors is more challenging. In order to make better decisions based on the real-time data, many supply chain companies have instituted “Control Towers” which track and trace shipments and monitor performance of suppliers against a range of metrics. If a shipment is delayed, this information is automatically relayed along the supply chain so that steps can be taken to re-route; re-order; source goods from elsewhere or take other remedial steps to ensure that disruption is mitigated.

291. Data is drawn not only from the buyer’s data systems, but from those of its logistics companies and even its product suppliers to provide visibility. Consultancy McKinsey described such a model as, “a supplier ‘x-ray’ solution that gathers procurement-relevant supplier data such as cost, lead times, capacities, inventories, and risks, along the whole value chain. Data sources for such a solution will include the proprietary systems of value chain partners, as well as structured third-party data and unstructured web feeds from many different sources, all combined into meaningful, real-time profiles of a company's tier-n supply chains” (McKinsey, 2016).

292. Whilst the technology exists to facilitate these data flows, the concept still relies on the willingness of supply chain parties to share what in some cases may be regarded as commercially sensitive data. Consequently, trust becomes an important factor in achieving the highest levels of supply chain visibility.

293. The aspiration is that data will “replace” inventory. That is, greater supply chain visibility will mean that manufacturers and retailers are able to make better decisions leading to lower levels of buffer stock. This will be a critical tool for many companies, allowing them to remain responsive to customer demand whilst minimising capital tied up in inventory.

Author Recommendation 7
The government can play a role in the development of new technologies by fostering an environment of innovation and business investment. It can also help with the adoption of these technologies by supporting skills training, research and development and capital investment tax advantages. For example, this could encourage the adoption of technologies by SME manufacturers in the domestic UK supply chain which would allow them to engage in PPE and healthcare equipment frameworks.

294. The concept applies equally to government procurement organisations although the tools used are often less mature, according to consultancy Boston Consulting Group (BCG). "The public sector typically does not have full visibility into its supply chain, the analytics to identify supply chain risks and bottlenecks, or the simulation tools to optimise supply chain networks for efficiency and resiliency", it commented, although this situation is changing rapidly as software already available in the private sector is adopted (Hemmige et al, 2022).

295. The authors of the paper cite an example in which BCG developed a Control Tower during the Covid-19 pandemic for a "large national public health agency" in the US. The challenges it faced included:

- supply spread over multiple private sector players;
- complex product categories;
- limited catalogue standardisation; and
- evolving visibility priorities and needs from stakeholders.

296. In other words, many of the same problems faced by healthcare providers in the UK.

297. The Control Tower solution involved working with suppliers to develop data flows enabling visibility of:

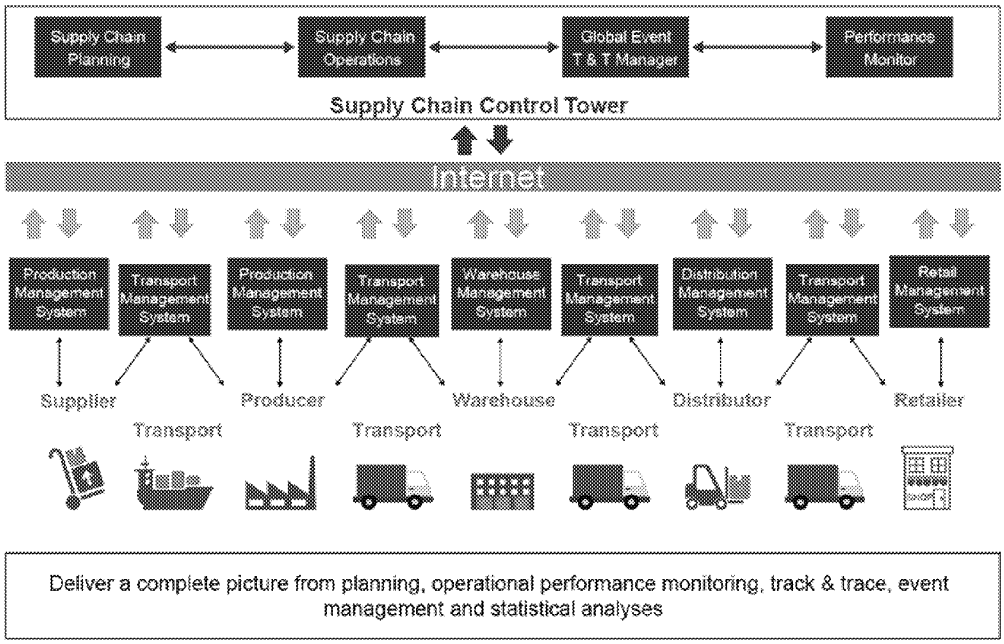
- orders;
- inventory levels; and
- material flows.

298. This was then matched against hospital-reported stock levels and Covid-19 caseloads to assess the risk of shortages. Decision-support tools made stakeholders aware of potential problems and gave them the ability to take action to avert them. Its benefits included:

- centralised visibility of supply chain performance against key performance metrics;
- insights to make supply chain decisions;
- tailored forecasts of demand;
- simulation of performance under various scenarios;
- identification of supply chain vulnerabilities, such as production or supply bottlenecks; and
- improved inventory strategy.

299. Regarding this last point, BCG asserts that the implementation of Supply Chain Control Towers can bring about a reduction in inventory of 10-15% whilst maintaining service levels (Hemmige et al, 2022).

Figure 19. The role of the "Control Tower" in providing supply chain visibility



Source: (Author, 2019)

300. Higher levels of visibility will also enable more fragmented stock holding. It will no longer be necessary to consolidate inventory in centralised distribution centres to keep stock levels low. *Data* will be centralised rather than *inventory*, which will reduce risk. This potential is discussed in more detail below.

301. South Korea has been cited as an example of best practice in relation to the use of data infrastructure and analytics during Covid. As one research paper asserted, "Countries that leveraged data analytics and digital technologies were better equipped to anticipate shortages, allocate resources efficiently and avoid overstocking…South Korea's use of data analytics and a centralised platform for PPE distribution facilitated rapid response and effective allocation during the crisis" (Kumah et al, 2023).

302. Advances in technology will also enable new techniques and processes which reduce the emphasis on large, low cost labour forces. These include flexible manufacturing, higher levels of automation and robotics and 3D printing. Amongst other benefits, this will allow manufacturers to locate their production closer to end markets with potential implications, as already discussed, for the UK's PPE and Healthcare Equipment market.

Section 4: Supply Chains before the pandemic

Section Summary

Prior to the onset of the Covid-19 pandemic, the UK government had developed a Pandemic Influenza Preparedness Plan as a result of earlier global pandemic scares such as H1N1, SARS, MERS and Ebola. Part of these plans involved the establishment of stockpiles of PPE and healthcare equipment. Further stockpiles were developed to deal with a potential "no deal" exit from the EU.

In terms of "business as usual" inventories, the NHS in England had developed a supply chain policy focused on cost reduction through the establishment of a centralised procurement organisation, NHS Supply Chain. Despite this, Trusts still preferred to buy and stock much of their own PPE and healthcare equipment. Procurement and supply in the DAs was much more centralised, supplying nearly all of healthcare providers' needs.

Whichever downstream distribution model was in place, all supply chains in the UK were impacted by a lack of visibility of upstream suppliers, a problem which affected all countries. South Korea was one of the best prepared in terms of inventory strategy, but even it took the decision to put in place export bans to protect domestic stocks. The UK's own ability to supply its own PPE and healthcare equipment needs was compromised by a lack of manufacturing capabilities and investment in automation. It can be concluded that preparedness planning did not take into account global shortages of critical healthcare products and this should be rectified in future exercises.

The UK's emergency supply chain strategies and structures prior to the pandemic

303. Pandemic Influenza Preparedness Plans (PIPPs) had already been established in the UK prior to the Covid-19 pandemic: in 2011 (DH, 2011); 2007 (DH, 2007) and 2005 (DH, 2005). Influenza was regarded as the most likely cause of a pandemic by the UK's National Risk Register of Civil Emergencies (NRR). These were adapted to respond to the Covid-19 pandemic due to certain similarities (infection via airborne droplets of fluid), the latest iteration of the plan being the UK Influenza Preparedness Strategy 2011. The most relevant aspects of the "defence in depth" plan to the supply of PPE included:

    - surveillance and modelling to assess the impact of the virus and identify groups most at risk; and
    - reducing the risk of transmission through the provision of "pre-identified" PPE for front line healthcare workers.

304. Exercises, such as those detailed later in the report, tested the effectiveness of the plans and the administrative structures which have been developed. Exercise Cygnus, undertaken in 2016 to test resilience to influenza, led to a draft Pandemic Influenza Bill which subsequently was used as the basis for the Coronavirus Act 2020.

305. The most notable emergency supply chain initiative in place before the pandemic was the establishment of PIPP stockpiles following the Swine Flu outbreak in 2009 (SCCL statement, INQ000492085, para 17.1).These were held in each of the four nations of the

UK as part of a coordinated approach and provided an essential part of the governments' early pandemic response. For England, the PIPP stockpile was designed to support the first 26 weeks of a Reasonable Worst Case Influenza Pandemic (SCCL statement, INQ000492085 para 17.20). The DHSC is responsible for joint procurement for the four nations under a memorandum of understanding. Once acquired, the product is distributed to local distribution facilities, in the case of Scotland, Wales and Northern Ireland, under DA ownership. The UK government's New and Emerging Respiratory Virus Threats Advisory Group (NERVTAG) advises on the volumes and type of PPE that should be stockpiled and for which eventualities.

306. A Department of Health paper, *Health and Social Care Influenza Pandemic Preparedness and Response*, published in 2012, stated that, "The distribution strategy for these products would ensure that the NHS is supplied with an initial push of products [from the PIPP] which are likely to be in high demand as they are not used in the quantities which might be needed in a pandemic (including products such as facemasks and respirators) or are specific to the response (such as the vaccine consumables). Other products would be on a more demand-led basis and local stocks might also continue to be used, or supplemented by central stocks" (DH, 2012). It was also commented that it might take 7-10 days for products to be distributed across the country and so reliable local stocks would be important.

307. In England, the PIPP stockpile was overseen by Public Health England (PHE) on behalf of the Department of Health and Social Care. In turn, the management of this stockpile, amounting to 323 million items on 9 October 2019 (DHSC statement, INQ000528391, para 900), was contracted to another public body, Supply Chain Coordination Limited, which manages NHS Supply Chain. The DHSC stated that the largest proportions of the stocks were held ready to use in the first 15 weeks of a reasonable worst case scenario (RWCS) pandemic flu outbreak (DHSC statement, INQ000528391, para 194). It was planned that these would be augmented as required through the provision of JIT contracts with suppliers (ibid, para 194). The logistics were carried out by a private sector service provider, Movianto, from a warehouse in Haydock (SCCL statement, INQ000492085, para 17.2).

308. PHE also coordinated procurements on behalf of the DAs (Scottish Government statement, INQ000498141, para 17). In Scotland, 44 million items were held in two locations managed by NSS on behalf of the Scottish Government which had ultimate authority over when to release products. To put this figure into perspective, by 6 April 2020, NSS was shipping 24.5 million items weekly (AS, 2021).

309. The Welsh Government's PIPP stockpile, containing around 22 million items, was held in a warehouse in South Wales and distributed by Shared Services, initially on a "push basis" to healthcare providers throughout the country. By April stock levels were particularly low across a number of products, especially gloves (AW, 2021).

310. In Northern Ireland, the stockpile (owned by the devolved Department of Health) held 20 million items including, uniquely in the UK PIPP stockpile, surgical gowns which had been bought at the time of the swine flu outbreak in 2009. These were still usable due to their long shelf lives. Despite the inventory being of use in the "last resort" 63% of stocks had been drawn down by the end of April 2020 (NIAO, 2022).

311. There were also other PPE resources developed as a response to the threat of disruption to UK supply chains from a no-deal exit from the EU. A stockpile in England was managed directly by the DHSC. It consisted of six weeks' worth of PPE and healthcare products (at a business-as-usual rate of use) which would be difficult to source from the EU in the event of trade disruption. It was considered that sourcing from elsewhere in the world would not be affected by a no-deal exit (SCCL statement, INQ000492085, para 18.2). As it became evident that the stock was no longer needed for these purposes, the decision was made to transfer the inventory to NHS Supply Chain on February 11, 2020 to support the pandemic response (DHSC statement, INQ000528391, para 216).

312. In Northern Ireland, BSO PaLS, the organisation in charge of managing the DA's healthcare procurement, had built up stocks ahead of a potential no-deal exit although these only amounted to one week's supply at the rate of consumption in early 2020 (NIAO, 2022). Shared Services in Wales had obtained a large warehouse to store additional PPE for the same contingency. It was reported that it was large enough to hold six weeks stock at "business as usual" usage rates (Williams, 2019). In Scotland, NSS said that it had added eight weeks' supply of medical goods to its inventories (including PPE and healthcare equipment) at normal usage rates, at a cost of £5 million. NSS Procurement Director commented, "We tend to replenish our stock around 13 times a year - about once every four weeks and in preparation for this potential disruption to supply chain we've increased that by around four to eight weeks of some of those products that are used absolutely the most regularly" (Rayo, 2019).

313. The Scottish Government relied on its agreement with the UK government to replenish stocks of PPE using JIT arrangements with manufacturers. These contracts, as it turned out, were ineffective in the face of global market pressures during the pandemic (NSS statement, INQ000521969, para 92).

314. In Northern Ireland, hand hygiene, clinical waste products and syringes were delivered under similar contracts but other JIT contracts, including one for the supply of 6.8 million FFP3 face masks, were cancelled by the DHSC due to suppliers' inability to fulfil their obligations (NIAO, 2020). This situation was also mirrored in Wales where JIT contracts, which had been relied upon to increase PIPP levels to 15 weeks if needed, did not deliver to expectations (AW, 2021).

315. A DHSC paper commented on the UK's preparedness that, "Both influenza and the virus that leads to Covid-19 cause respiratory disease and spread in a similar way, largely via small droplets of fluid from the nose and mouth of someone who is unwell. These similarities meant that certain elements of our pandemic preparedness plans were able to be quickly utilised and adapted in our response to Covid-19." However, the paper also noted that "important differences" meant that not all aspects of its plans could be applied (DHSC, 2020).

The structure of UK healthcare supply chains and their resilience before the pandemic

316. To assess how the "business-as-usual" UK PPE and healthcare supply chains responded to the stress placed upon them by the Covid-19 crisis it is necessary to understand how and why they developed as they did in the years before the pandemic. As already

discussed in the first section of the report, decisions made to minimise inventory and costs can result in higher levels of supply chain vulnerability.

317. Levels of procurement centralisation vary across the four nations. As already explained, in Scotland, Wales and Northern Ireland almost all PPE and healthcare equipment is purchased through the central buying organisations: NSS, Shared Services and BSO PaLS, respectively. The Scottish Government has consulted on increasing levels of centralisation of purchasing and supply of PPE and other healthcare equipment on behalf of all public sector organisations and social care providers. In England, in contrast, there are much higher levels of fragmentation and although the majority of supplies are purchased centrally, hospital Trusts account for a much bigger spend.

318. Since 2019, most goods used in the NHS in England have been procured by NHS Supply Chain (NHS SC), a wholly-owned government entity established to centralise purchases with an £8 billion annual budget. The new organisation came about as a result of the conclusions of the 2015 "Carter Review" commissioned by the UK government.

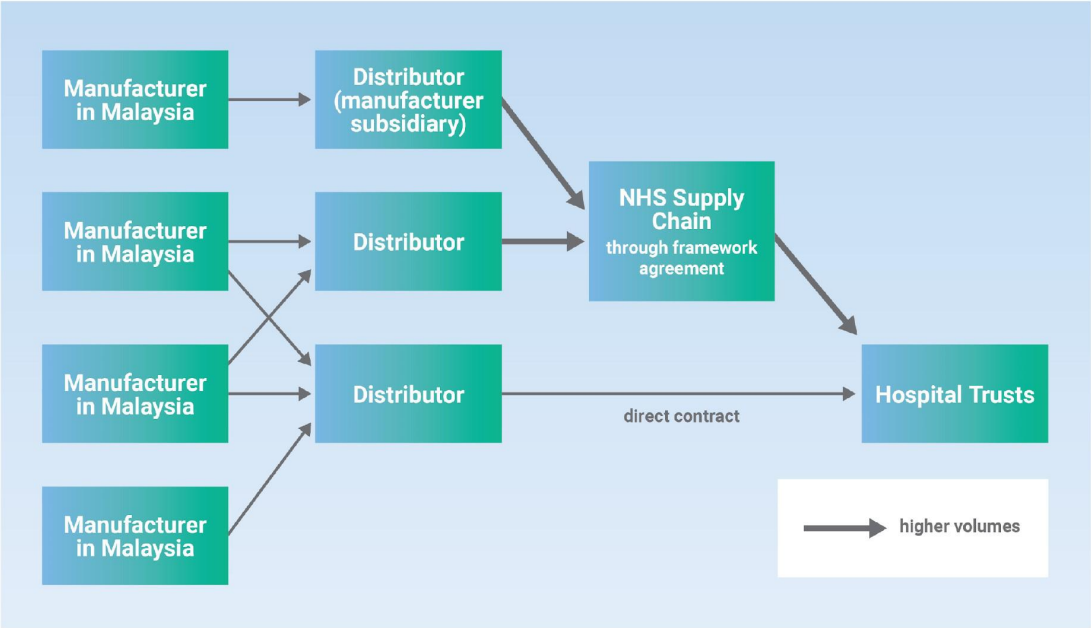
319. The report by Lord Carter of Coles looked at how the productivity and efficiency of the NHS in England could be improved. It recommended that cost reduction could be brought about through procurement consolidation and reduced stock holding. Although referring to medicines rather than PPE, it highlighted an NHS and wholesaler partnership in Avon, Gloucester and Wiltshire: "One trust has seen their stock holding shrink from 35 days to 19 days, reducing costs from £3.13 million to £1.72 million" (DHSC, 2016). The same ethos and principle to consolidation and stock reduction applied to all supplies procured by the NHS, including PPE.

320. NHS SC's aspiration remains to take over an increasing amount of procurement from hospitals and other health service providers with the aim of leveraging economies of scale as well as assuring consistency in the prices being obtained. Its five-year plan in 2018 envisaged ultimately being responsible for 80% of the market – doubling the proportion for which it had formerly accounted. At the launch of its new operating model in 2018, it stated, "Working as part of the NHS, the new NHS Supply Chain will deliver clinically safe, high quality products for the best possible value, and aims to realise £2.4bn of savings in its first five years of operation" (NHSSC, 2018).

321. NHS Supply Chain organises its procurement through so-called "Category Towers", comprising of clinical consumables, capital medical equipment, PPE and non-medical products such as food and office solutions. It consolidates orders from over 600 healthcare service suppliers and, prior to the pandemic, was managing 4 million orders per year.

322. Figure 20 shows a typical downstream supply chain for the medical gloves category which although relates specifically to NHS SC could equally apply to the DAs' buying organisations. Within the Framework Agreement running up to March 2022, there were 19 approved suppliers to NHS Supply Chain, the vast majority sourcing goods from Malaysia, the most important glove producing market at the time.

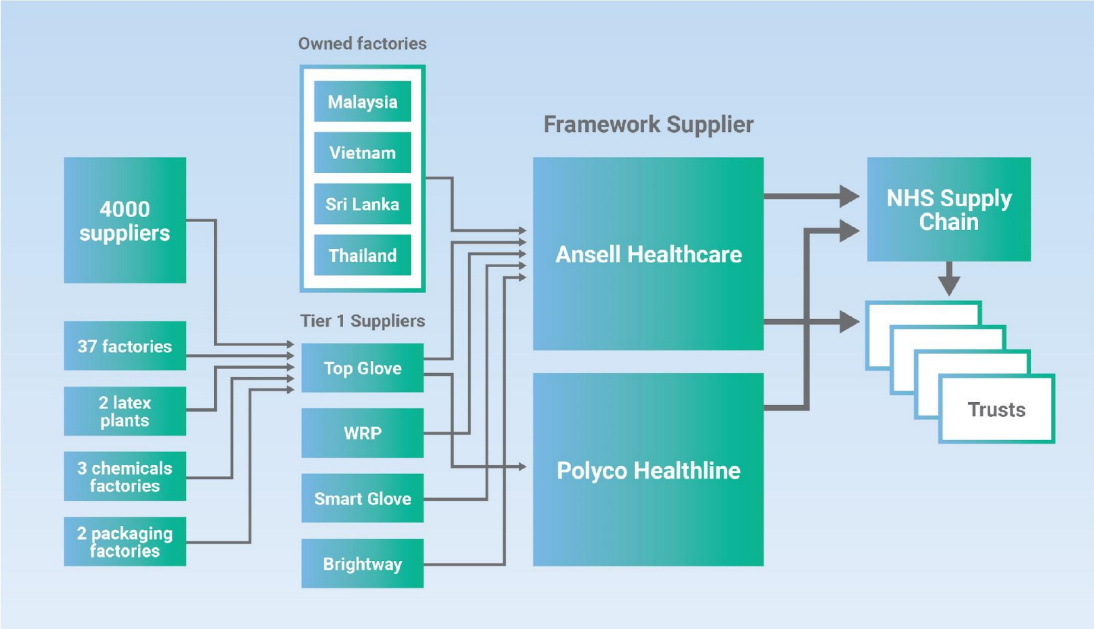
Figure 20. Medical glove downstream supply chain



Source: (NHS SC/Author, 2022)

323. The upstream supply chain is much more complicated, as shown in Figure 21 for Ansell Healthcare, one of the approved Framework Suppliers to NHS SC. Ansell sources and distributes goods to NHS SC from its own factories located in Malaysia, Vietnam, Sri Lanka and Thailand as well as sourcing products from a number of Tier 1 suppliers. These include Malaysian company, Top Glove, which has 37 glove factories, 2 latex factories and 4,000 suppliers of its own. During the pandemic, Top Glove products were also being sourced through UK distributors by the Department of Health and Social Security. In addition, Top Glove also supplies other NHS Framework Suppliers, such as Polyco Healthline, demonstrating the complexity of the supply chain and the types of consolidation of risk which might occur.

Figure 21. Medical glove upstream supply chain



Source: (Author, 2022)

324. In theory, consolidation of buying power at a UK level would create the ability to exert more influence on global upstream markets. Based on my knowledge of private sector procurement, this influence is lessened every time buying power is subordinated, in the case of PPE and healthcare equipment procurement to a DA or to the healthcare provider level. Indeed, I believe the complexity, number of buyers and lack of visibility of demand in the market meant that, going into the pandemic, there was already a sub-optimal procurement structure and this contributed to the UK's difficulties in responding to the pandemic. The problems relating to a lack of understanding of the nature and volume of demand meant that central buyers were unable to place orders with any degree of confidence or, indeed, distribute appropriate levels of healthcare equipment to healthcare providers.

325. The steps taken by the UK government and DAs at the outset of the pandemic indicate the belief that the problems experienced by PPE and healthcare equipment supply chains could have been mitigated by more centralised management, procurement, visibility and planning. Since the pandemic, reports and consultations have recommended further centralisation of procurement as a way of increasing resilience (Unipart, 2022) (SG, 2022). However, centralised procurement systems are certainly not seen by all as a panacea for the supply chain problems faced by the PPE and healthcare equipment sectors. This is evidenced by the fact that many healthcare providers (such as Trusts in England), given the choice, still prefer to buy their own supplies. As SCCL itself says NHS Trusts can sometimes buy products more cheaply when, "a supplier wishes to increase its market share by selling direct to customers" (SCCL statement, INQ000492085, para 7.7).

326. One view is that the complexity of the structures established by DHSC have prevented greater uptake by the Trusts (Boiko et al, 2020). The authors of the paper argue that the large number of intermediaries and private and public sector organisations have resulted in multiple contractual relationships with a variety of incentives and profit-taking at numerous levels throughout the supply chain. At the same time, they believe the Category Tower approach (which involves splitting procurement budgets into 11 separate categories) has resulted in a fragmented demand-side leading to loss of buying power and increased complexity. In the views of the authors, an implicit "de-centralisation" rather than "centralisation" has occurred leading to a loss of accountability and cost control. They believe that, in its present structure, NHS SC has reduced the UK's PPE and healthcare equipment supply chain resilience, rather than improved it. The arguments over the centralisation of the UK's PPE and healthcare equipment supply chain structures are discussed in more detail at paragraphs 566ff.

UK and international comparisons of inventory holdings and stockpile arrangements

327. Stockholdings of PPE, ventilators and test devices can be categorised between:

- emergency stockpiles held by the UK and devolved governments for use in the event of disruptions to supply in a healthcare emergency;
- inventory held by the public procurement organisations, local healthcare providers and other organisations in the public sector for "business as usual"; and
- inventory held commercially by private distributors and wholesalers to supply a range of public and private organisations for "business as usual".

328. Prior to the pandemic, individual PIPP stockpiles were held in:

- England – 323 million items (DHSC final draft statement, para 174)
- Scotland – 44 million items (AS, 2021)
- Wales – 22 million items (AW, 2021)
- Northern Ireland – 20 million items (NIAO, 2022)

329. Table 1 shows how long the stocks held in the PIPP stockpile managed by Shared Services in Wales lasted. It can be seen that whilst many categories of products lasted well into April/May 2020, levels of gloves ran down quickly.

Table 1: Quantity of items in the PIPP stockpile in March and long it lasted

Product category	Units in stock at the outset (1 March 2020)	How long it lasted (weeks from 9 March 2020)
Aprons	9,129,800	6.0
Eye protectors	3,144,000	10.2
Type IIR masks	4,906,000	5.5
FFP3 respirators	870,000	10.9
Gloves (singles)	4,814,000	1.5
Hand sanitiser	37,326	4.3

Source: (Shared Services (Wales))

330. Whilst there is a range of values, in terms of the key suppliers of PPE, Polyco, as an example, had an average of 60 days of inventory for the period which included the first few months of the pandemic. This figure would be representative of many other companies across the consumer goods sectors although it would be based on "business as usual" levels of usage. During the pandemic, these holdings were used up very quickly.

331. Prior to the pandemic, there was no single UK-wide complete inventory of PPE which could provide visibility of:

- government and DA owned and managed stocks;
- stocks held locally by Trusts, Boards and other health organisations;
- stocks held by other government departments and agencies (such as the Ministry of Defence);
- distributors/wholesalers' inventories; or
- UK manufacturers' inventories.

332. Specifically relating to the Trusts in England, the SCCL says, "A major difficulty with the system as it was set up was that…it had no way of tracking what the individual Trusts actually already had as there was no centralised information on inventory" (SCCL statement, INQ000492085, para 7.39).

Author recommendation 8

Compiling and maintaining a "digital twin" (a Control Tower overview) of the complete UK inventory of PPE and healthcare equipment through an inventory management system should be an aspirational post-pandemic goal. This should include stocks held by NHS SC,

DAs' procurement organisations, Trusts, Boards, primary and social care providers, manufacturers, distributors and public bodies. This would require the cooperation of all supply chain parties including the DAs. How this is done and the appetite for such UK-wide transparency of PPE and healthcare supply chains will require further investigation.

333. Many other countries faced the same issues as the UK in terms of stockpiles, as detailed below.

- The USA's Strategic National Stockpile consists of 12 warehouses. The organisation attracted criticism at the outset of the pandemic. It had only 12 million N95 facemasks which had been left over from an order placed in 2009 and 30 million surgical face masks in March 2020, a level which the Department of Health and Human Services judged to be 1.2% of what was appropriate (3.5 billion over a year) (Lovelace, 2020).

- In France, an inquiry in 2020 found that there was only a stockpile of 100 million surgical masks despite an independent inquiry's recommendation in 2018 to hold 1 billion. It was stated that a billion face masks bought in 2018 would have cost €27 million as opposed to €450 million it cost in 2020 (Amiel and Bairin, 2020). Stocks of masks had reduced from 1.7 billion in 2011.

- The Canadian government faced similar criticism. Supplies of PPE in its National Emergency Strategic Stockpile (NESS) which were acquired in 2009 had passed use-by dates and were consequently disposed of. This included 2 million N95 masks and 440,000 gloves (Leo, 2020).

- Australia's stockpile is managed by Australian National Medical Stockpile (ANMS). As of 31 December 2019, it was valued at AU$123 million and included 20 million masks (depleted from earlier severe bush fires) (ANAO, 2021). It was supplemented by State Stockpiles such as those held in Tasmania. The latter stored around 6 weeks of "business as usual" face masks, but only two days of gowns and was criticised by a subsequent audit for:

    - not accurately recording the quantity of PPE stock held at the beginning of the Covid-19 pandemic;

    - shortfalls in recommended levels of PPE; and

    - storing PPE which was not fit for use due to passing expiry dates or quality deficiencies (TAO, 2021).

334. South Korea's overall response to the Covid-19 pandemic has been widely praised. A National Stockpile had been established after the H1N1 influenza outbreak in 2009 and plans were introduced for real time stockkeeping management after the MERS outbreak in 2015. This involved a new Center for Public Health Emergency Preparedness and Response responsible for, amongst other things, stockpiling and distributing medical supplies (including PPE). Other stockpiles were held at local level by devolved governments with mechanisms in place to share PPE regionally through mutual aid (FDA,

2021). However, despite these preparations, the country too faced shortages in the first few months of the crisis and the government was forced to introduce the rationing of face masks and limiting exports to 10% of production capacity. It was better placed in terms of ventilators. An existing 10,000 ventilators and 300 oxygenation machines were sufficient to meet the country's needs, although a further 300 ventilators and 100 oxygenation machines have since been added to the country's stockpile (ADB, 2021).

The UK manufacturing base and its potential to scale production of key healthcare equipment

335. Due to elevated labour costs relative to emerging markets, the UK manufacturing sector has evolved towards the production of high value goods, dependent on high levels of sophistication and technologies. Directly supporting 2.6 million workers, accounting for £217 billion of GDP and ranking as the twelfth largest manufacturing nation in the world, the UK has a large, world class and efficient industrial sector (Make, 2024). Its impact on the economy is even more profound if the indirect and wider impacts of the manufacturing sector are taken into account. Its focus on higher value adding processes means that, in general terms, it does not compete in terms of costs with Asian, and specifically Chinese, manufacturers. This meant that before the Covid-19 pandemic almost the entirety of the country's need for PPE and healthcare equipment products was met through imports (with the exception of ventilators which will be discussed below). As the report by Oxford Economics (OE, 2024) confirms, "a relatively small share of UK manufacturing Gross Value Added (GVA) is contributed by the production of lower-value goods such as textiles and leather products, which may be more efficiently produced in low-cost locations overseas."

336. In addition, the UK does not have the size of workforce which would allow it to effectively scale up production. The production of many types of PPE relies on multiple human-led processes which are usually low skilled. Labour availability and flexibility are essential attributes which the UK labour market lacks.

337. Automation is an alternative to the deployment of large labour resources. However, as one industry commentator asserted during the pandemic "[UK] companies without automation already in place are looking to have machines built for automation in a matter of weeks, which is unrealistic. The current demands to increase PPE production cannot be temporary, as it would be expensive and unrealistic to automate quickly for a temporary surge in demand. Attempting to get automation in fast for a short-term process is not just expensive; it is the wrong strategy entirely" (Innomech, 2021). This indicates that investment in automation and 4IR technologies must be a long term policy commitment by the government in conjunction with investment by UK business. As well as wider economic benefits it would facilitate the growth of a sustainable PPE and healthcare equipment sector with the ability to scale up in an emergency. As one report puts it, "The workplace of 2030 will be a very different environment to that of ten years ago. The physical and cognitive capacity of machines will significantly disrupt the working practices and employment roles of the last decades while also offering the UK a golden chance to boost its languishing economy by embracing the transformative potential of autonomous systems" (UK-RAS, 2021). The UK government has said that it wants the country to become a "science and technology superpower" by 2030 and in 2023 pledged £370

million in funding to boost infrastructure, investment and skills to develop 4IR technologies (DSIT, 2023).

338. Labour and automation are just two of the elements involved in the ability to scale up production. It also relies on:

- sourcing the right raw materials in the right timescales at the right price;
- establishing relationships with suppliers, especially if operating in a new sector;
- the sourcing and installation of automated equipment; and
- the availability of skilled staff to install and program equipment.

339. The manufacturing of ventilators involves a different set of challenges to PPE and testing devices. They require the assembly of a range of electronic, plastic and mechanical components as well as batteries to not only supply oxygen and remove carbon dioxide but to monitor the lungs, control the airflow, humidity, temperature and air pressure. Production is highly technical; supply chains are very specialised and quality control essential. This level of complexity meant that it was very difficult for the UK businesses already involved in the production of ventilators to scale up production and even more difficult for other manufacturers to become involved (see "Ventilator Challenge" below for more detail).

340. One of the problems the UK faced in terms of PPE production was that whilst other countries either had PPE production capabilities which provided them with a foundation to scale up or sectors which could switch production to PPE from other lines, the UK had neither in any great supply. In contrast:

- market leaders such as 3M, Honeywell and Kimberly Clark are headquartered in the USA which provided a base for the US to increase its manufacturing of PPE (Hesson and Alper, 2020);
- India increased production by 57 times its usual level, leveraging its existing textile base; Bangladesh's production increased by 11 times and Vietnam's was 7 times higher by employing the same strategy (Garcia-Santaolla et al, 2021); and
- Taiwan increased mask production to 15 million pieces per day to become the second largest producer in the world (Chiang, 2020).

341. Up to half of additional PPE production in emerging markets was generated by textile manufacturers switching capacity to PPE to take advantage of the high global prices. This was seen as a low risk investment as, when PPE prices returned to pre-pandemic levels, these companies could return to the production of textiles as their main business revenues (Garcia-Santaolla et al, 2021).

342. In my opinion, the UK manufacturing sector, in general terms, found this step more difficult to take as:

- companies lacked the types of technology involved and required significant investment in non-core equipment;

- it had no "safety net" of being able to deploy their production lines post-pandemic back to textile manufacturing; and
- it faced high labour costs which made it difficult to build long term sustainable business models due to competition with remote, low cost labour markets .

Warning signs: preparations in place from previous health emergencies

343. Since 2000, the UK has experienced a number of health emergencies. Although these turned out to have only a minor impact in terms of number of cases and their wider consequences for the economy and society, they prompted a major response from the governments of the time in terms of planning and preparedness.

344. In 2003, the Severe Acute Respiratory Syndrome (SARS) outbreak resulted in 8,096 probable cases and 774 deaths worldwide. Whilst there were only 4 reports of suspected cases in the UK and no fatalities (UK Covid-19 inquiry, 2024), the government established the SARS Taskforce, involving representatives from relevant agencies and Devolved Administrations.

345. Following the outbreak, a paper drafted with help from the UK SARS taskforce concluded that, "Implementation of the phased contingency plan response raised a number of issues regarding NHS acute and primary care trust (PCT) preparedness. The most notable of these concerned the purchase and supply of personal protective equipment (PPE) consumable items such as masks, gowns and respirators, as clear lines of responsibility were difficult to identify. Implementation of infection control guidelines, including appropriate staff training were also highlighted as areas of concern" (Goddard et al, 2006).

346. In 2011, the UK government, Welsh and Scottish devolved administrations jointly published the UK Influenza Pandemic Preparedness Strategy 2011 putting forward proposals for, "an updated, UK-wide strategic approach to planning for and responding to the demands of an influenza pandemic". It superseded the 2007 National Framework for responding to an influenza pandemic. The paper was designed to take account of the lessons learnt from the H1N1 Swine Flu pandemic of 2009-10 and "inform the development of updated operational plans by local organisations and emergency planners" (DH, 2011).

347. With the exception of face masks, the report makes little mention of the use of PPE in healthcare settings and then only briefly. In Paragraph 4.16 of the report it says, "The Government already has in place stockpiles of facemasks and respirators for health and social care workers. In line with the scientific evidence, the Government will not stockpile facemasks for general use in the community". No recommendations as to the appropriate stock levels were made.

348. In order to test for preparedness to deal with the impact of epidemics and pandemics, the government has conducted exercises as part of its contingency planning. It did so on 11 October 2014 in the wake of an outbreak of the Ebola Virus Disease (EVD), involving a range of ministers, agencies and health professionals, as well as a simulated meeting of

COBR. Part of the legacy of the EVD outbreak was the initiation of the High Consequence Infectious Diseases (HCIDs) programme.

349. One of the conclusions of the exercise was the need for standardisation of PPE ensembles across the NHS. That is, all health professionals should wear a specified set of PPE, rather than relying on local preferences or, crucially, availability. As one research paper asserted, "the aim was for items selected to be available within the NHS supply chain, to allow access to all UK users, since bulk-buying of non-core items such as coverall suits resulted in procurement issues during the EVD outbreak" (Poller et al, 2018). The exercise found that no appropriate hood existed and the NHS subsequently commissioned a specific design.

350. The PPE required to be worn by medical professionals when dealing with suspected Ebola patients was extensive and comprised:

- respirator (FFP3);
- head protection (hood);
- eye protection – full face visor;
- gown, overlapping boots;
- apron, wide, medium thickness plastic apron;
- three layers of gloves; and
- boots: surgical wellington boots (Poller et al, 2018).

351. This full PPE "ensemble" is appropriate for the prevention of infection through bodily fluids (a characteristic of EVD). It was also recommended that the same set of PPE should also be used to prevent infection by airborne diseases such as MERS. However, this was not the approach taken with Covid-19 with specific advice changing over the course of the pandemic as more became known about the disease. If the advice had been followed, considerably more, and different, PPE would have been required.

352. Following an outbreak of Middle East Respiratory Syndrome (MERS) in 2015, another simulation exercise, "Alice", was commissioned by the UK government to assess levels of preparedness for an epidemic. The exercise took place on 15 February 2016. A subsequent report, undertaken by England's former Chief Medical Officer, Dame Sally Davies, concluded that, "the level and use of PPE was central to the exercise dialogue and considered of crucial importance for frontline staff" and that, "pandemic stockpiles were suggested as a means to ensure sufficient quantities were available" (Iacobucci, 2021). The report also noted that despite learnings from Ebola on infection control understanding, "clear instruction for PPE level and use was recommended" (PHE, 2016).

353. In response to criticism that it had originally blocked the release of the report during the Covid-19 pandemic, the government said, "MERS-CoV does not transmit as easily as SARS-CoV-2 [Covid-19] between people, outbreak sizes are comparatively small, and the risk to individuals in the UK remains very low....The results of exercise Alice have been incorporated into ongoing planning work conducted by DHSC, UKHSA, and the NHS to

respond to potential outbreaks of high consequence infectious diseases like MERS-CoV" (Booth, 2021).

354. In terms of coordination across the whole of the UK, the Devolved Administrations of Scotland and Wales were involved and the report concluded that a coordinated response would be essential to control the spread of the disease.

355. However, of the actions identified, it must be stressed that only one of twelve related to PPE provision: "The development of MERS-CoV specific instructional video on PPE level and use."

356. It is also to be noted that the 14 simulation exercises which took place between 2003 and 2018 (listed in annex 1) did not take into account what would happen if there were a global shortage of PPE. This was an obvious shortcoming which should not be repeated in future resilience exercises.

Author Recommendation 9

Exercises which test the UK's preparedness for a pandemic should take into account global shortages of PPE and specifically assess inventory levels and scalability of domestic production in the face of export bans imposed by foreign governments, even those regarded as friendly.

Section 5: Supply Chains during the pandemic

Section Summary

The UK's PPE and healthcare procurement systems and supply chains were established during a period of "business as usual" to drive down costs through efficiencies of centralised buying, achieving goals of value for money and freeing up budgets to be spent on front line services. They were not designed to deal with a surge of demand for PPE and healthcare equipment caused by a pandemic.

The mechanism to deal with demand for PPE caused by health emergencies was the PIPP and EU Exit stockpiles, combined with JIT manufacturing contracts. As it transpired, these contingency measures proved inadequate to deal with demand. As a result of this, combined with the failure of existing supply chain functions, many local healthcare providers in England took on the role of attempting to procure their own additional supplies. When this approach threatened to result in chaos, the UK government stepped in, establishing the Parallel Supply Chain. Whilst this initiative was necessary, it too faced criticism for being too bureaucratic and not agile enough to take advantage of market opportunities. Different arrangements existed in the DAs using centralised procurement and supply structures.

Ensuring product quality was a problem due to a breakdown in existing supplier relationships, the complexity of product standards and a lack of training amongst all supply chain parties on how to deal with quality regulations.

From the time when it became clear that the PIPP stockpiles were inadequate and that centralised purchasing organisations in the four nations would not be able to meet the demands of the healthcare, primary and social care organisations through existing suppliers, the government seemed on the back foot, making decisions in reaction to events. Whilst the problems were recognised at an early stage and a solution was developed in the form of PSC, the new organisation lacked data on which to make distribution decisions; the models it created vastly over-estimated the future demand for PPE and many of its sourcing decisions were questionable in terms of value for money. Many of these problems were as a result of a lack of resilience planning before the pandemic which resulted in policy and supply chain strategy being developed as the crisis unfolded.

The impact of the pandemic to UK and global healthcare equipment supply chains

357. A fundamental problem which health organisations faced in the procurement of PPE and other healthcare equipment was determining the volumes which would be required. This was partly as a result of unknown infection and patient hospitalisation rates at the outset of the pandemic and challenges in forecasting future demand. There were huge disparities in the forecasts which were being provided to governments and hence it proved impossible to estimate accurately the number of gowns, masks, aprons, visors and gloves which were required to treat those people affected.

358. This was not the only problem. At various times throughout the crisis, governments adjusted the guidance on the frequency of use of PPE by Healthcare Workers. This related specifically to the number of times that PPE should be changed throughout the day. At the outset of the crisis, the guidance was that an item of PPE should be changed after the treatment of every individual patient. When stocks started to run low, however,

this guidance was changed allowing the sessional and re-use of PPE (DHSC statement, INQ000528391, para 627).

359. Technical advice also varied from country-to-country on who should wear items of PPE. Some countries insisted that members of the general public should wear masks when travelling outside of their house, for example, when using public transport. Although not necessarily being to the same standard as equipment used within a medical setting, this guidance placed additional pressures on existing stocks of PPE.

360. Erratic buying behaviour and the inability to forecast accurately meant that huge orders were placed by procurement professionals desperate either to prevent shortages or replenish ever-diminishing stocks. As already discussed, this resulted in the "bullwhip effect" where even small variances in order quantities by parties at the end of the downstream supply result in much larger orders upstream and excessive levels of inventory being held to meet demand. In the case of the Covid-19 pandemic, however, the situation was far more chaotic resulting in the PPE market becoming dysfunctional.

361. Multiple buying organisations placed multiple and duplicated orders with multiple suppliers. This type of behaviour was mentioned by SCCL in relation to attempts to manage demand for PPE and other healthcare equipment at the outset of the pandemic. "Demand control (rationing) was not routinely communicated [to Health Trusts] at the start of the pandemic as this often serves to encourage customers to place multiple orders to get around any rationing" (SCCL statement, INQ000492085, para 7.32).

362. More generally, behaviour such as this, however understandable, inflated prices and disrupted buyer-seller relationships. Little or no inventory was left in stock, meaning that as PPE was produced it was shipped. With no safety stock, shortages and delays were endemic as global distribution networks buckled under the sheer volume of shipments with an underperforming logistics industry weakened by the impact of the disease.

Price volatility of healthcare equipment on the global market

363. An increase in demand for PPE, Covid-19 restrictions on manufacturing capacity, logistics disruption, a focus on domestic supply in China and bans on exports of PPE by many governments, resulted in a spike in prices on the global market, especially in the early days of the pandemic.

364. Reviewing various sources, such as data published by Shared Services Wales and Bown (2022), it can be observed that, in general terms, prices rose in the first quarter of 2020, peaking in the second quarter before falling back in the third and fourth quarters; in the case of goggles to pre-Covid-19 levels.

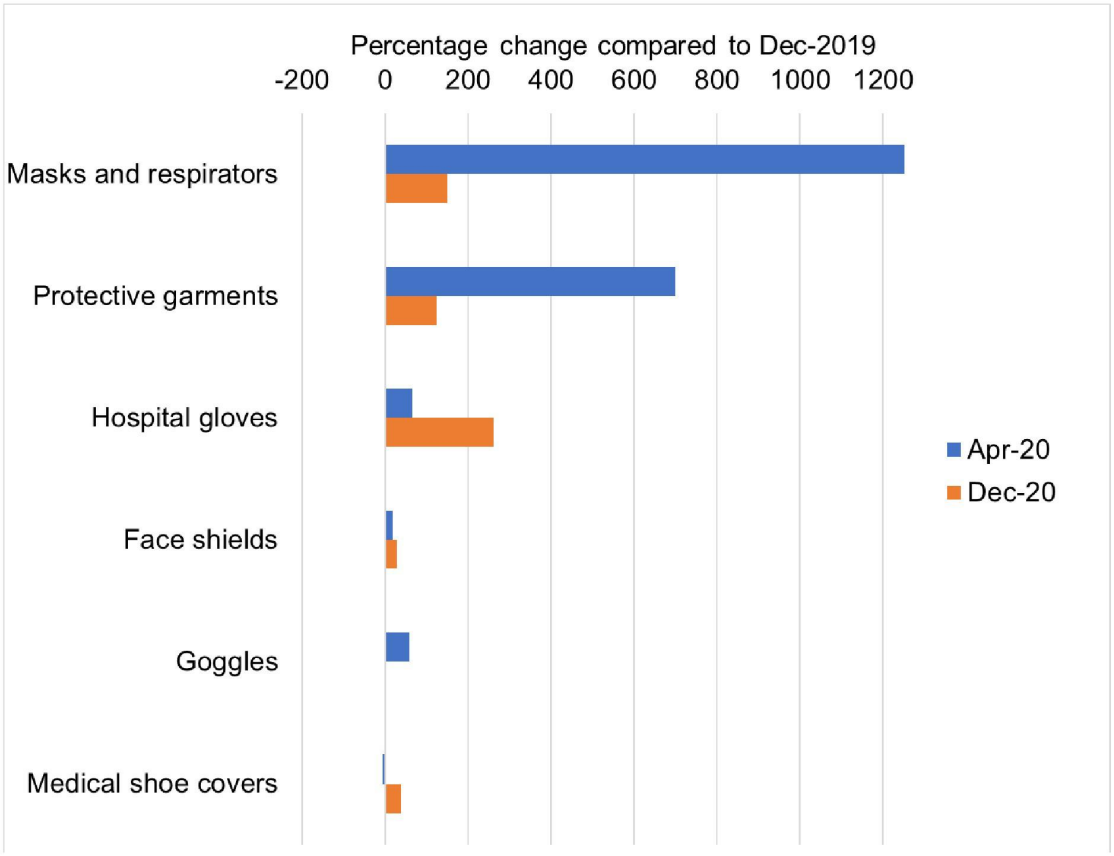
365. It is reported that Chinese export prices for masks and respirators were 1252% higher in April 2020 than before the pandemic and for protective garments they were almost 700% higher than pre-pandemic levels (Bown, 2022). The value of China's exports of PPE increased from $22.9 billion in 2019 to $88.1 billion in 2020 (this figure includes a combination of volume and value increases).

Table 2: Trade prices (unit values), percent changes in Chinese export prices to EU

Product	In April 2020 vs December 2019	At peak vs December 2019	In December 2020 vs December 2019
Masks and respirators	1251.7	1251.7	149.3
Protective garments	698.8	698.8	124.4
Hospital gloves	66.9	262.0	262.0
Face shields	18.5	32.4	27.2
Goggles	57.3	57.3	-0.4
Medical shoe covers	-6.4	41.5	37.9

Source: (Bown, 2022)

Figure 22. Trade prices (unit values), percent changes in Chinese export prices to EU



Source: (Bown, 2022)

366. In terms of the impact on prices in the UK, Northern Ireland's procurement agency, Business Service Organisation (BSO), acquired gowns for between £0.68 and £1.24 per

piece on 13 April 2020, but costs had increased to a range of £4.87 and £5.85 by 29 April 2020. Not only had the prices risen but the range of the prices had also increased. One supplier had offered gowns at £15 per piece, although this offer was rejected.

367. According to Independent Healthcare Providers (IHCP) (Northern Ireland) between January 2020 and September 2020 the prices of a pack of 100 gloves rose from £1.55 to £7.95 and 200 aprons from £2.95 to £6.95.

368. Shared Services in Wales published the following table:

Table 3: Average unit price for main categories of PPE

		Average Unit Price (£)
Type IIR masks	Nov-19	0.24
	Apr-20	0.40-0.73
	May-20	0.35
	Jun-20	0.20
	Oct-20	0.05
FFP3 respirators	Nov-19	4.80
	Apr-20	6.49
	Jun-20	4.76
	Oct-20	5.50
Nitrile Gloves	Nov-19	0.03
	Apr-20	0.15-0.25
	May-20	0.135
	Oct-20	0.095
	Nov-20	0.08
Gowns	Nov-19	1.41
	Apr-20	4.5
	May-20	2.5

Source: (AW 2021 (from Shared Services Wales))

369. This shows a consistent trend. Prices peak in April 2020, falling back in May and thereafter. In the case of masks, the price in the third quarter of 2020 was significantly below the level it had been pre-Covid-19. When looking at other parts of the UK, the peak is generally reached in April, although for some items prices peak in March, May or June.

370. The return of the global market price to "business as usual" prices (in some cases lower) and the stockpiles built up in the UK and the rest of the world (both as a result from deliberate procurement decisions and over-ordering during the pandemic) are a considerable barrier to the sustainability of UK production of PPE. This point is discussed at length below.

Restrictions and constraint on global production and supply

371. Exports of PPE from China dropped in January and February 2020 (face masks, for instance, by 24%), affected by the Chinese New Year and the shutdown of China's manufacturing sector during the first wave of Covid (Bown, 2020a). At this time there was a surge in imports to China from the rest of the world which meant that when the virus spread to other countries, the global inventory of PPE had already been drawn down. One estimate suggests that the reduction in Chinese exports and the import of PPE from the rest of the world had a net result of 31.6 million fewer kilograms of face masks alone in the global inventory (Bown, 2020a). When Chinese production was scaled up, it was focused on domestic requirements rather than exports to the rest of the world although by March 2020 China's balance of trade in PPE had almost returned to parity. That being said, the policy of rebuilding its own domestic inventories meant that it did not come close to meeting the booming demand for PPE and other healthcare equipment elsewhere in the world.

372. The outbreak of the disease in China in January and February led to an increase in imports to the country of PPE of 8.7 million kg, but a reduction in exports of 22.8 million kg as China prioritised its own healthcare needs (Bown, 2020a). By March 2020, the position as regards the balance of imports and exports had stabilised. The Chinese Customs authorities claimed that daily exports of PPE increased by 150% over the period of April.

373. The US has historically been the biggest consumer of Chinese PPE products for the health sector. The considerable resources of many of its hospitals, as well as well-established trading partnerships with Chinese manufacturers, meant that even at the outset of the spread of Covid-19 (when it had relatively few cases) it was increasing its stock of PPE at the expense of other worse affected countries, such as Italy.

374. In terms of restrictive trade measures, China was not alone in restricting the export of PPE. The German government also placed a ban on exports as German manufacturers were unable to meet the required domestic demand. The French government requisitioned all stocks of face masks for use by medical staff and also placed a ban on exports (SCCL statement, INQ000492085, para 13.7). For French PPE manufacturers, this meant that even existing orders from organisations such as the NHS could not be fulfilled, even if they were long standing customers. Part of the French government's justification of this action was that it prevented PPE entering the "secondary market" at

inflated prices. This severely impacted the UK's strategy to augment PIPP stocks with JIT supplies, especially face masks (DHSC final draft statement, INQ000528391, para 293).

375. In addition (amongst many others):

- The EU announced region-wide restrictions on the export of PPE as a response to the German legislation, hoping that such moves would maintain the single market.
- Authorisation was also required for PPE transiting the EU, meaning that shipments destined for the UK through ports such as Rotterdam and Antwerp could be delayed.
- Between January 2020 and April 2020, more than 220 actions limiting the export of certain goods (including PPE) were undertaken globally (CRS, 2021).

376. The World Trade Organisation (WTO) commented, "Export restrictions are not a solution to supply shortages. Quite the contrary, they send a devastating signal and thus cause domino effects. No country produces all the products needed for medical care or the necessary intermediate products. If every country holds back its goods, no country will have all the (medical) products needed to cope with the pandemic."

Author recommendation 10

Through its influence in the WTO the UK government must encourage major PPE and healthcare equipment manufacturing markets to maintain normal trading relations during pandemics. In addition to this, when negotiating bilateral trade deals, the use of export bans, particularly for critical medical products, should be discussed and if possible assurance of supply (that is, assurances that exports of critical goods such as medicines or PPE will not be blocked) should be written into any formal agreement.

Disruption to international and domestic logistics services

International transport arrangements

377. As well as production constraints and export restrictions, supply of PPE and other healthcare equipment was also impacted by logistical considerations. PPE is normally moved by sea due to the relatively low price per unit. However, as the virus spread in the West, movement shifted to air due to low global inventory levels and the increase and urgency of demand. Sea freight from China to the UK typically takes between 20-30 days depending on the speed of travel and the number of calls.

378. When air passenger services were suspended on a worldwide basis, there was, as a result, a significant drop in air cargo uplift capacity from China. Passenger bellyhold capacity had dropped by 70% by the end of March 2020. Indeed, for most of the crisis there was a chronic air cargo capacity shortage out of China with lead times between a week and two weeks depending on the route.

379. The high demand for PPE and the willingness of non-price sensitive governments to pay multiples of usual air cargo rates resulted in the re-purposing of passenger aircraft to "passenger freighters", sometimes with boxes being stacked on seats. All-cargo freighter flights also increased. In March, there were 528 additional cargo charter flights from China which amounted to five times as many charter airline slots as compared with the year before.

380. Military aircraft were also used to provide uplift. The RAF was asked by the government to move a shipment of PPE from Turkey at the height of the shortages. Uplift from China for foreign military air forces was more challenging to negotiate although German, Algerian and Russian air forces were able to land at Pudong Airport, Shanghai to collect shipments of PPE. The US Air Force was also involved in the transport of medical materials, such as swabs for testing, from Italy to Memphis where they were distributed through FedEx's network. Russia provided an An-124 cargo aircraft to move PPE from Moscow to the US in early April.

381. According to FedEx, in May, PPE exported from China made up more than 80% of its air transport volume to both the United States and Europe. As a result, it added hundreds of extra non-scheduled flights between China and the United States and Europe.

382. Between March 2020 and 28 June 2022, imports of PPE and healthcare equipment to the UK were managed by the DHSC's National Supply Disruption Response (NSDR). During this time it handled approximately 15.9 billion items (DHSC statement, INQ000528391, para 595). Its last air cargo shipment was moved in September 2021 whilst the last sea freight shipment was imported into the UK on 29 May 2023 (ibid, para 598).

383. The British Embassy in Beijing played an important role in securing flights from China to the UK. When an agreement with air express operator UPS fell through in early April 2020, new deals were agreed with British Airways and Virgin to re-open daily freight-only flights on passenger routes (Former DIT statement, INQ000527714, para 13.81).

384. Shipments of PPE and healthcare equipment, once paid for, were either received from the manufacturer in the country of origin or delivered to the UK. Those received in the country where they were produced were shipped by DHSC's freight forwarder, Uniserve, and tracked on its system 'One World'.

Rail freight alternative

385. An alternative to air cargo, with its high price point and longer lead times than usual, was the rail "landbridge" from China to Europe.

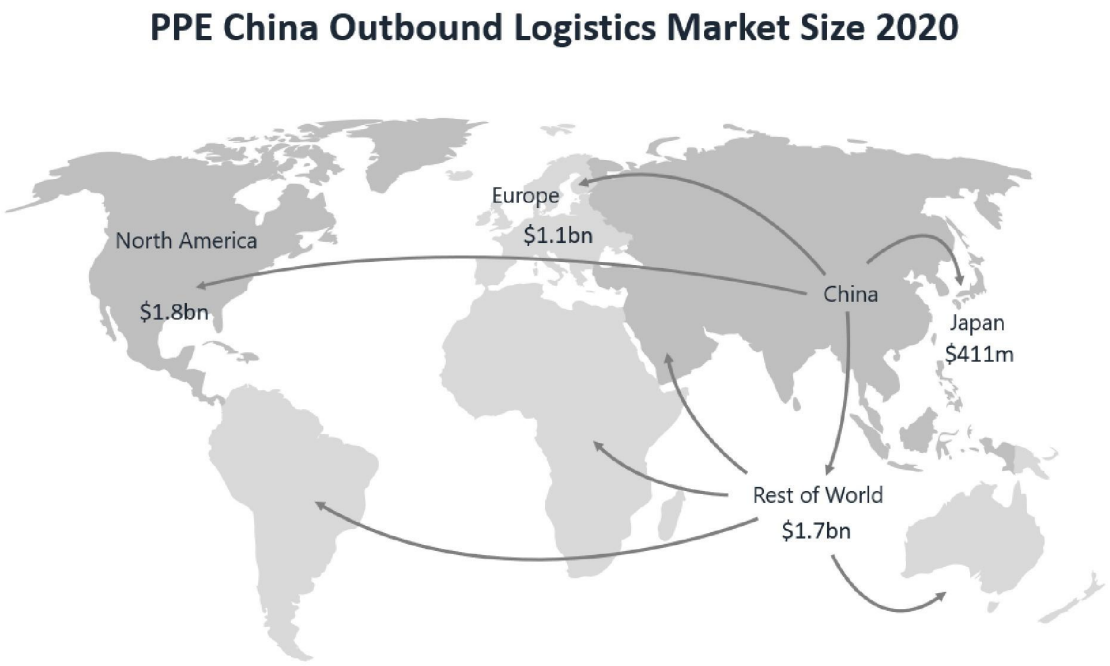
386. As an example, in April 2020, DB Schenker set up an operation moving 186 containers of PPE from China to Italy, specifically supplying the badly affected Lombardy region. In total, the shipments included more than 1,300 tons of protective overalls and goggles from various manufacturers in Shanghai and Hubei. They were collected by truck at the production sites, moved to a container terminal in Xi'an and transferred onto a service operated by DB Schenker and DB Cargo. The transit time to Kaliningrad was twelve days via Kazakhstan, Russia and Belarus. From there, the containers were transported by ship to Rostock, from where they were again taken by train to DB Schenker's intermodal terminal in Verona. In total, the transit time took 15 days. After customs clearance, the

containers were finally distributed to health facilities in Milan, Bergamo and Brescia, amongst others, by truck.

387. The NSDR introduced rail movements of PPE and healthcare equipment from China to the UK in May 2020 (DHSC statement, INQ000528391, para 597).

388. Given the hostilities which have developed between Russia and Ukraine subsequently and the tensions which exist between Russia and the West, this route may not be a secure option in the future although there are rail links which do not involve transit through Russia.

Figure 23. PPE China Outbound International Logistics Market Size 2020



Source: (Author, 2020)

389. The biggest channel spend on transportation services was the China-North America market followed by Europe (including the UK). The flow of PPE from China to Japan was also sizeable. Outside of these major lanes, the market is large but fragmented.

Customs clearance and Trade Compliance

390. The surge in demand for PPE and the largely cross-border nature of supply placed huge stress on freight forwarders and Customs agencies from the perspective of:

- export licensing;
- approvals by quality control agencies and activity by Quality Inspection companies;
- correct Tariff Code Classification; and
- other border processes.

391. In order to facilitate the flow of PPE, agencies became more flexible, loosening existing regulations on declarations. In addition, some Customs agencies introduced the following initiatives:

- instead of original documents, electronic documents could be presented to Customs by email;
- some national authorities waived Customs penalties incurred; and
- the amount of information required for a shipment of PPE was reduced.

392. However, despite these steps, some freight forwarders reported clearance backlogs at ports and airports. These were caused by the impact that Covid-19 had directly on Customs organisations through infection of officers as well as:

- increased workloads for testing;
- the sheer volumes of PPE being exported; and
- new, inexperienced shippers entering the market.

393. Some countries in the EU removed the levy of duties on the import of certain types of PPE for charities. According to the website EU Law Live at the time, "In normal circumstances, face masks may be subject to a 6.30% duty, surgical gloves to a 2% duty and protective spectacles and visors, to a 2.90% duty, plus VAT at the rate applicable in the Member State of the importation." However, there are contingencies in EU law which allow Members to take steps to remove duties in the case of emergencies and several applied to the European Commission to this effect. The US and UK followed a similar route.

Last mile delivery – getting the items to where they needed to be

394. Another major problem faced by all governments in the UK was the difficulty in getting PPE to the frontline health professionals when and where it was required. The centralised distribution networks which existed were not designed to facilitate the flow of product to the many thousands of healthcare settings which found a sudden need for PPE. These included primary care/doctors' surgeries; pharmacies and social care providers.

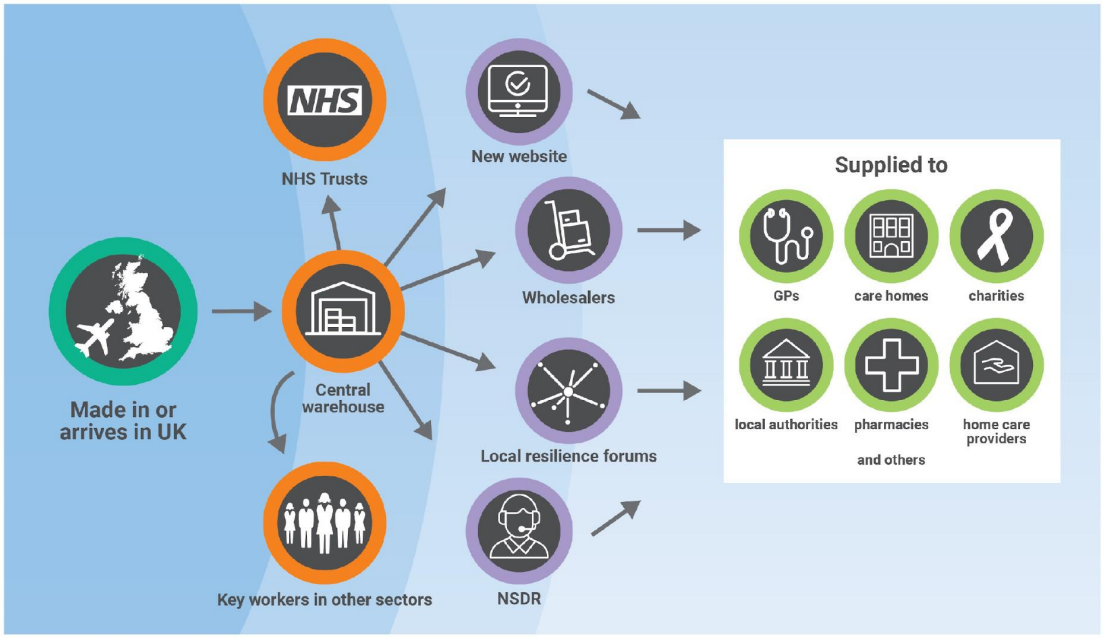
395. The DHSC used a combination of public/private resources including the Armed Forces to supply hospital trusts at a local level as well as selling PPE to wholesalers who could then supply the fragmented primary health sector including dentists and care homes. At the outset, the supply was based on estimated rather than actual need and this resulted in PPE and healthcare equipment being "pushed" out to healthcare providers. As the DHSC commented this was due to demand being driven by both "necessity and caution" (DHSC statement, INQ000528391, para 591). It also prevented "over-ordering and hoarding by organisations to the detriment of the rest of the system" (ibid, para 613). As the pandemic progressed, actual usage figures became available to central planners which allowed for more precision in matching supply with demand.

396. The "Parallel Supply Chain" (PSC) was established (see below) which took over the responsibility for the procurement and distribution of PPE and healthcare equipment. In terms of the impact on the downstream operations, this allowed products to be distributed

faster whilst allowing the established supply chain to remain operational for other non-PPE products. The NSDR system was also set up to expedite smaller shipments in the case of urgent need (DHSC, 2020b).

397. According to SCCL (which continued to manage the distribution of PPE and healthcare equipment after the establishment of PSC) the logistics operation to supply the NHS and social care sectors had to be developed "from scratch" (SCCL statement, INQ000492085, para 14.7). Even basic information such as delivery addresses, location details, how much was needed, the forecast of demand and which customers might be supported most effectively was not available. Transitioning to delivering to small healthcare or social care settings, many of which were only open in normal business hours, was very challenging. NHS Supply Chain's own distribution operations had been set up for "large lorries to large customers" (ie Health Trusts) working on a 24/7 basis (SCCL statement, INQ000492085, para 16.1).

Figure 24. England's PPE downstream supply structure



Source: (DHSC/Author)

The role of stockpiles in pandemic preparedness

398. Stockpiles are an effective way of mitigating supply chain risk emanating from either demand or supply shocks, both of which were evident during the Covid-19 pandemic. Their role in preparedness for future pandemics or other emergencies has been recognised by the World Health Organisation (WHO), which developed a Framework subsequently adopted in 2011. Amongst its benefits, the WHO claimed that the Pandemic Influenza Preparedness (PIP) framework would result in, "improved risk management through establishment of stockpiles and/or provision of: pharmaceuticals, personal

protective equipment and other supplies necessary during the response to an outbreak" (WHO, 2011). The UK published its Influenza Pandemic Preparedness Strategy in 2011 in which it stressed that it already had in place stockpiles of facemasks and respirators (DH, 2011). The UK's PIPP stockpile had been established following the Swine Flu outbreak in 2009 (SCCL statement, INQ000492085, para 17.1).

399. However, stockpiles require intensive management especially given the "perishable" nature of PPE and other healthcare equipment. Use-by dates mean that stock should be "rotated" (sold or donated to users) in order to prevent the need for disposal. Even more management is required of high tech medical equipment such as ventilators. These need continual maintenance including the monitoring of batteries to make sure that, when called upon, they still work.

400. Establishing the "right" level and type of inventory is also critical. This depends on guidance from medical experts on the frequency of use of PPE and varies depending on the disease for which is being prepared. The government repeatedly stressed that the UK's stockpile was designed to meet the needs of an Influenza pandemic rather than Covid-19. However, if this is the case, in my opinion, it raises the question of why a "disease-agnostic" PPE and healthcare equipment strategy was not in place.

401. As described below, it is possible to maintain stockpiles "virtually" which reduces many of the costs involved. However, these inventory management strategies also depend on a reliable and fast replenishment through JIT/Quick Response manufacturing. This would mean that manufacturers would be called on to switch resources at short notice to produce the types of PPE and healthcare equipment which were required by healthcare providers. Not only would this require strong relationships with suppliers but it would depend on the manufacturers involved having the requisite levels of agility. Even then, JIT contracts proved ineffective during Covid-19 as the manufacturers themselves found it impossible to source materials to meet their contractual obligations.

402. Furthermore, to reduce the risk of the impact of national export bans imposed by trading partners, this strategy would have to rely on a domestically-based PPE manufacturing sector.

Author recommendation 11

The importance of stockpiles had been recognised by government as an important tool to supply PPE in the early stages of a pandemic. However, in my opinion, more consideration needs to go into what the stockpile contains and its management and maintenance.

Developing a "disease-agnostic" PPE and healthcare equipment strategy involves a much broader focus than just maintaining higher levels of stock (the problems with this have already been discussed at length). A holistic supply chain approach is required, encompassing demand and demand-modelling; inventory visibility; assurance of domestic and international supply; robust trade and transport systems, all coordinated by a single Control Tower function, informed and regularly updated by experts in epidemiology and infection prevention and control.

The adaptation of supply chains during the pandemic

Product quality and testing

403. Before PPE products can be placed on the market, they are required to comply with an extensive set of regulations. Although some of these regulations were eased during the Covid-19 pandemic in order to speed up the supply of PPE and other equipment to the market, exporting and importing these products is far from straightforward. This is due not least to the complexity of product categorisation involved in multiple Customs' agencies nomenclatures. Border agencies also often play a key role in making sure that imported products meet trading standards. This means that all parties must be aware of what a particular piece of PPE has been designed for and whether it meets the required standard.

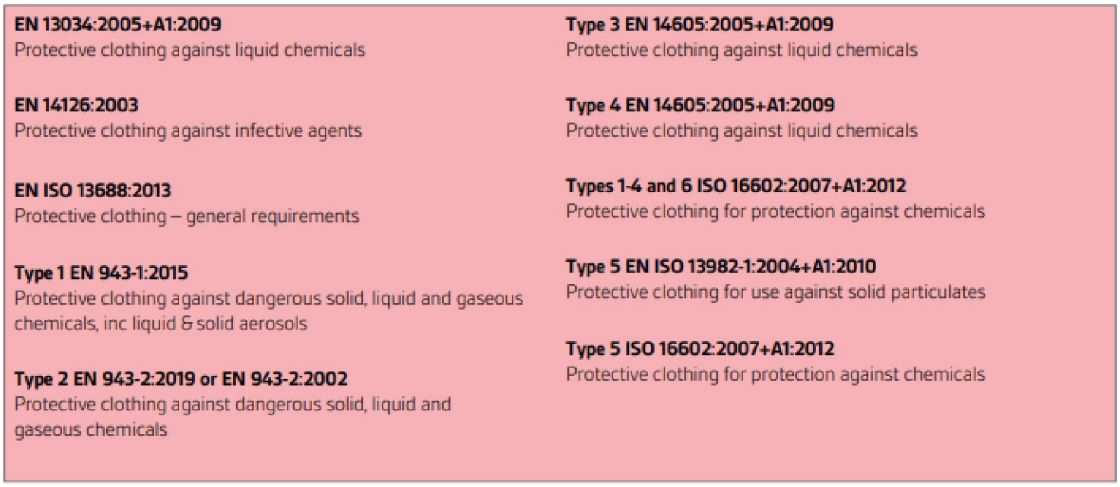
404. For example, some types of products that appear to be similar to PPE may actually be regulated and categorised as "medical equipment" or a "protective medical device" if their main purpose is to protect others from the user (as opposed to protecting the wearer from others in which case it is considered PPE) (MHRA statement, INQXXXXXXXXX, paras 23-24). Thus, trade in the sector can be complicated by a host of documentation requirements which can cause delays in the shipping of goods, especially if processes have not been digitised. The UK's Medicines and Healthcare products Regulatory Agency (MHRA) provided training and documentation to the UK Border Force during the pandemic to help identification of non-compliant devices (ibid, paras 87-88). It asserts that between March 2020 and March 2023, 20,619,501 non-compliant individual devices (such as masks, gowns and gloves) were prevented from entering the UK.

405. Whilst politicians, procurement, supply chain and logistics professionals all came under pressure (and in turn exerted pressure) to expedite the supply of PPE to hospitals and other medical settings, this could not be achieved at the cost of product quality. As the UK government wrote in a guidance document, "PPE that doesn't meet the essential health and safety requirements should not be supplied and won't be used, as it could not be ensured to protect against the risk of infection" (DHSC, 2020a). The regulatory authority, the MHRA, asserts in its statement that whilst it did not ease the regulatory requirements for medical devices, it did "operate flexibly" issuing Exceptional Use Authorisation (EUAs) and providing guidance on fast-tracked approvals (MHRA statement, INQXXXXXXXXX, para 106). 56 EUAs were issued between March and September 2020, compared to just 3 in the same period in 2019 (ibid, para 112).

406. The UK government claimed that it worked with 15,000 PPE suppliers to process 23,000 cases to ensure that safety and quality standards were met, engaging with 99% of those which offered their services.

407. Complicating the issue, there are a number of different standards worldwide with which PPE has to conform. For illustrative purposes only, Figure 25, excerpted from a document supplied by a standards' organisation, shows the number of clothing standards in use with healthcare products. Similar standards exist for gloves, visors and masks.

Figure 25. Clothing Standards in use with healthcare products



Source: (ISO, 2020)

408. Similar standards exist in the US, specifically ANSI/ISEA 125-2014, American National Standard for Conformity Assessment of Safety and Personal Protective Equipment.

409. The UK adopted European Commission standards as part of the EU Withdrawal Act 2018 (some provisions apply differently in Northern Ireland as a result of the Windsor Framework). Manufacturers must affix the UKCA marking to either items of PPE or, if not possible, to their packaging (in Northern Ireland, CE UKNI) (OPSS, 2023).

410. Since the UK's exit from the EU, "distributors" of PPE in the UK have become "importers". This means that they have additional legal obligations such as checking that manufacturers based in the European Economic Area (EEA) have undertaken the required conformity assessment.

411. The standards required of PPE for use by the public are not as high as those required for medical staff. In France, 85 million out-of-date medical grade face masks, which had been destined for disposal by burning, were repurposed for use by the general public.

412. What is clear is that the production and import/export of PPE is not straightforward. As well as a knowledge of the various levels of conformity, suppliers must ensure compliance with the regulatory regime of each market into which they are shipping their products. This level of awareness must also be demonstrated by border agencies, trading standards agencies, customs brokers and freight forwarders, in the case of the latter, working on behalf of the shipper. When billions of items of PPE are being shipped around the world, this is highly challenging.

Author recommendation 12

Regulatory complexity related to product quality and compliance would be mitigated by the introduction of a single global standard, labelling and trade processes or, at least, mutual recognition of standards. However, whilst this should become a UK trade policy goal, in the meantime focus should be placed on training all parties involved in the import of PPE and

other healthcare equipment. Not only would this increase the quality of products on the market during a pandemic by reducing sub-standard goods but it would reduce Customs clearance issues which delay shipments at ports and airports.

413. Another issue which became evident during the Covid-19 pandemic was that until testing has been completed, often occurring on entry to the country of destination, it is impossible to know whether the shipment can be used or not. If it is rejected it will be returned to the shipper and new PPE must be sourced. Not knowing the "true" level of inventory makes planning and forecasting almost impossible, hence one of the reasons why purchasing organisations tended to place multiple orders.

414. Following criticism resulting from the high volume of exports which failed quality tests in the importing market, the Chinese authorities subsequently introduced testing at source, although this inevitably increased the time it took to ship the goods. According to one report, 9,000 new manufacturers started producing and shipping PPE in the first two months of 2020 which created issues in terms of quality control and adherence to trade regulations (IE, 2020). Before the new controls came into effect, exporters only had to have certification from the importing market (such as the EU's CE certification). However, this was easily counterfeited, unlike domestic regulatory processes and documentation.

415. In this respect, out-sourcing of production adds to the problem. Several tiers of suppliers sit underneath the distributor/exporter which signs the deal with the Western buyer meaning that it is often difficult for the main manufacturer to undertake quality controls.

416. This does not just relate to China, although as the largest exporter of PPE it has the highest incidence of quality issues. As manufacturers around the world rushed to enter the lucrative market, quality control became a real problem as highlighted in some of the examples below:

- There were issues with a shipment of 400,000 gowns from Turkey to the UK which attracted national media attention (Mason et al, 2020). Checks at Heathrow Airport highlighted that not all met safety standards. Consequently, further tests were undertaken both in Turkey and the UK before a proportion of the products were released to market;
- 600,000 face masks imported from China to the Netherlands were found to be defective (Payne et al, 2020);
- 100,000 masks supplied to Belgium from Colombia were similarly defective (Spinks, 2020);
- Slovakia, the Czech Republic and Spain returned thousands of faulty Covid testing kits supplied from China (Kern, 2020); (McArdle, 2020);
- A defective batch of 400,000 face masks supplied by Chinese company Garry Galaxy led to the isolation of 1,000 Spanish healthcare workers (Wilkinson, 2020); and

- Australian border control seized 800,000 face masks imported from China (Greene, 2020).

417. The problems resulted from the inability of existing, well-established suppliers to fulfil the needs of the global market. This forced procuring organisations to find new sources of PPE and healthcare equipment, often from untried and untested suppliers. The transactions on the open market and the urgency to procure products meant that there was little or no opportunity to gain an understanding of the supplier or the supply chain involved. Implementing many of the measures recommended in this paper to enhance supply chain resilience, especially by deepening relationships with suppliers and providing them with more opportunity to meet pandemic-level demand, will go some way to ensuring that such problems do not recur.

Author recommendation 13

Quality control issues with PPE and healthcare equipment and the subsequent rejection of many shipments were a result of a breakdown of supplier relationships as well as complexity relating to technical standards. Implementing resiliency measures such as maintaining strong supplier relationships throughout a crisis and simplifying standards should mean it will not be necessary to reduce border controls and administrative processes to fast-track shipments of PPE at the expense of quality. This will have positive implications not only in terms of ultimately getting more product to hospitals and other health and social care settings, but will ensure more accurate inventory management.

Clarity of labelling and accuracy of inspections

418. Labelling is critical to the quality assurance process, demonstrating compliance with industry standards and that the product has passed the necessary quality inspections. During the pandemic, PPE shipments had to show a "CE" or (from 1 January, 2021) the UK Conformity Assessed (UKCA) mark along with a number which would confirm that it had been manufactured following the correct processes and independently assessed by an accredited organisation. There are now 19 such approved bodies in the UK (compared with over 100 in the EU) which are able to assess conformity.

419. In order to provide more flexibility during the height of the shortages, the government allowed re-testing of expired PPE and over-labelling with new dates. In one case involving face masks, a use-by date originally set for 2016 was over-labelled with an expiry date of 2021, raising fears amongst HCWs. The DHSC commented on concerns, "The products that pass these stringent tests are subject to relabelling with a new shelf-life as appropriate and can continue to be used. All that are not up to standard will be destroyed" (Gilroy, 2020). SCCL confirmed that re-testing of PPE equipment, such as FFP3 facemasks, by the original manufacturers was a normal part of the stock control process. Products that passed tests (including "accelerated ageing") could have their expiry dates extended from, say, five to ten years, as seems to be the case in the example cited above (SCCL statement, INQ000492085, para 17.29). Passing product life extension tests is not a foregone conclusion. The DHSC stated that following testing some eye visors suffered

from clarity issues and most types of IIR masks failed splash resistance tests (DHSC final draft statement, INQ000528391, para 854).

420. Despite this assurance, whether or not this approach is sensible or appropriate has been an issue for political debate. Responding to a written parliamentary letter in 2002, Health Minister Edward Argar said that the government was looking at allowing the use of 303 million out-of-date items of PPE. "We are currently exploring whether these expiry dates can be extended to allow the products to be used". Whilst this may involve scientific testing, the minister did not make this explicitly clear (Pickard and Cameron-Chileshe, 2022).

421. However, in supply chain terms product life extension does have ramifications. Extending use-by dates has an impact on inventory levels and the level of stock which is available for distribution. It is likely to result in over-ordering of new stock if forecasts/models are based on inaccurate data.

422. The opposite can also be true if quality control inspections result in shipments being rejected; supply chains will then contain less product than figures would suggest. The situation is further complicated if those in charge of procurement start to factor in a certain level of rejections to orders. Procurement matching supply with demand then becomes guesswork and this is one of the reasons for the massive levels of over-ordering which occurred during the pandemic, exacerbated by fears over infection rates and other factors already discussed.

Author recommendation 14

Labelling and testing, along with usage guidelines (eg frequency and appropriate use) have clear supply chain consequences. Use-by dates should be an accurate guide to the safety of a product and its timeline for degradation, if kept in the requisite environment. Re-testing should be regular and taken into account in inventory management systems. The number of Quality Assurance organisations should not be a bottleneck for the approval of PPE and the UK government should "stress test" the sector to ascertain how quickly products could be accurately assessed in a pandemic.

Quality standards should be reviewed regularly to make sure that they are set at an appropriate level which safeguards HCWs but does not lead to unnecessary waste.

The consequences for existing supply

423. On 30 January 2020, the UK government established the "Supply Chain Cell" to manage the challenges of supply. This consisted of key stakeholders including the DHSC, NHSE, PHE, SCCL and Medicines and Healthcare products Regulatory Authority (MHRA) as well as counterparts from the DAs. It looked at new sourcing, inventory management and stock allocation and held daily meetings (DHSC statement, INQ000528391, para 223).

424. As has been already discussed, existing stockpiles of PPE were depleted within a few weeks of the pandemic. The focus of the UK government was to use existing and new suppliers to replenish these stocks. Its stated aim in September 2020 was to increase the

levels of stock held from two weeks at the beginning of the pandemic to four months (120 days) by November 2020 (DHSC, 2020c).

425. As of 3 March 2020, there were 1.44 weeks of FFP3 respirator masks, 1.07 weeks for eye protection, 1.38 weeks for IIR masks and 12.09 weeks for gowns left at the current rate of usage in SCCL warehouses (DHSC statement, INQ000528391, para 276) (including EU Exit stocks but not PIPP). No data was available on the supplies held by healthcare providers.

426. Throughout much of March and April 2020, the central procurement organisations in the UK had very few days of inventory on hand, sometimes relying on a single shipment to replenish critical stock levels (Iacobucci, 2020). This meant that as new supplies were being received from existing and new suppliers (through the Parallel Supply Chain) they were being distributed immediately to healthcare providers and other settings.

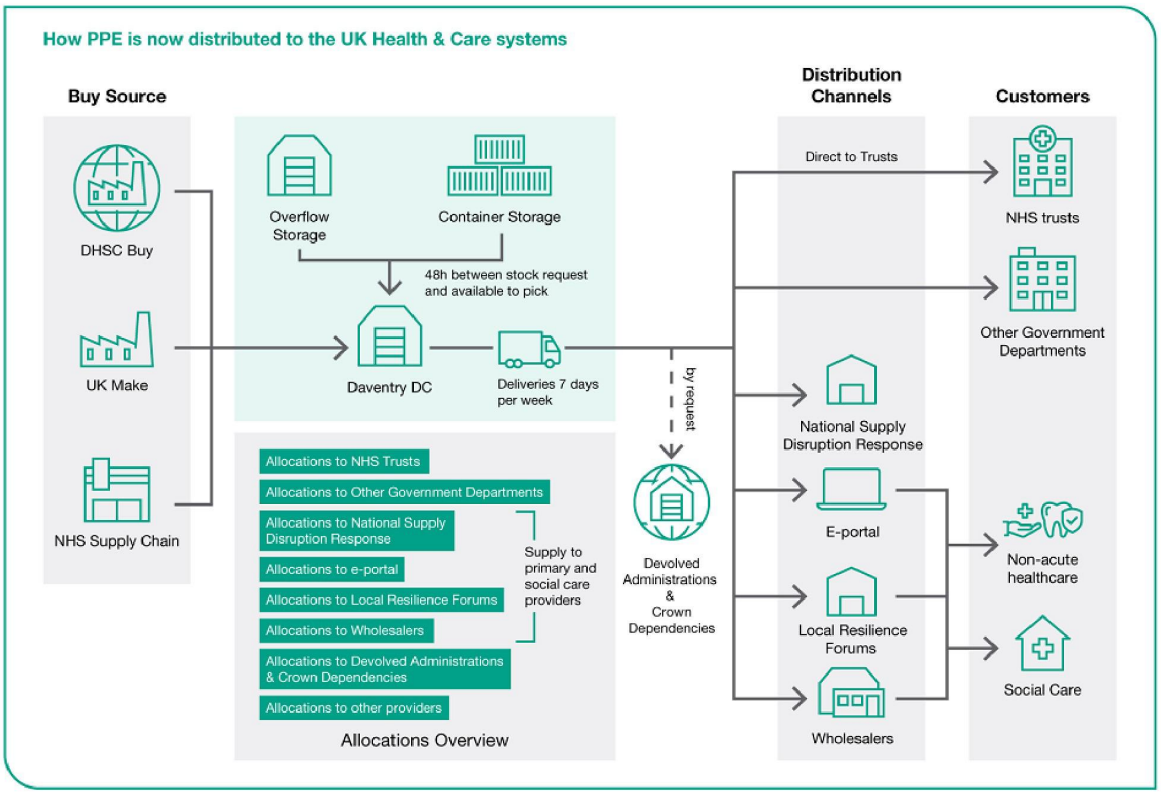
427. By May 2020, the situation was gradually improving as PPE and healthcare equipment orders arrived from China and elsewhere. The DHSC stated that it had one day of inventory on hand.

428. The situation was also improved as more visibility of locally held stocks was obtained. Up to early May, the DHSC had been "pushing" out deliveries of PPE to healthcare providers based on statistical modelling of need. This was replaced by a system which more accurately reported inventory levels and needs for specific categories of PPE.

429. Figure 25 shows the distribution channels put in place by the DHSC during the pandemic (by November 2020).

430. As already discussed, before this system was initiated, in England, PPE and healthcare equipment were centrally distributed to healthcare providers through NHS Supply Chain or procured directly by Hospital Trusts. In Scotland central distribution was undertaken by NHS National Services Scotland (NSS), Shared Services in Wales and in Northern Ireland, Business Services Organisation Procurement and Logistics Service (BSO PaLS). Across the UK, primary and social care providers were largely responsible for ensuring their own supplies. The Scottish Government states that the levels of PPE being delivered to the DAs through UK-wide procurement channels in the early days of the pandemic, were limited. This resulted in what it termed 'significant' costs being incurred (Scottish Government statement, INQ000498141, para 224).

Figure 26: The new PPE distribution channel developed to supply the UK Health & Care systems in 2020



Source: (DHSC, 2020c)

431. The downstream supply chain had to adapt to heightened demand for PPE and healthcare equipment from a range of different sources. In England, as well as the NHS Trusts, these included primary care providers and pharmacies as well as social care providers. In March and April 2020, the DHSC arranged emergency drops to surgeries, pharmacies, dental centres and hospices amounting to 22 million items (DHSC, 2020c). Local Resilience Forums (LRFs), established in conjunction with Local Authorities, were given the responsibility of distributing PPE from April 6, 2020 to local settings. In the first week 34 million items of PPE were provided to LRFs (DHSC, 2020b).

432. The DHSC also arranged emergency drops of 7 million items in this time period to CQC registered care homes and social care providers, with a delivery of at least 300 face masks to meet immediate requirements. After this initial supply, 23 million items were released to established wholesalers to provide onward distribution to registered care providers (DHSC, 2020b).

433. In addition, a UK-wide National Supply Disruption Response (NSDR) system was established for emergency PPE requests. This involved a helpline and call handlers who would prioritise requests and arrange express delivery of packs of limited lines of PPE if required. Between March 16 and April 9, 2020, 3,000 emergency packs were delivered in this way (DHSC, 2020b).

434. A new website for ordering PPE was under development by the DHSC in April 2020, designed to facilitate a more efficient way of ordering PPE for primary and social care providers as well as public service and local authorities. The e-Portal or PPE Portal, as it is known, enabled the ordering of 8.75 billion items of PPE between April 2020 and September 2022 (DHSC, 2022b). A later version was launched in January 2022 on which were registered 46,955 organisations. It is now managed by NHS Supply Chain. The PPE Portal was developed in partnership with online retail platform, eBay, Clipper Logistics, Royal Mail, Volo and Unipart to take over from the LRFs and wholesalers, creating a more efficient, centralised way of supplying the fragmented primary and social care market (DHSC statement, INQ000528391, para 658).

435. Scotland, Wales and Northern Ireland faced a similar challenge as the role of their procurement and supply organisations expanded to primary and adult social care. In Scotland, a scheme allowed 1,200 organisations in the regulated care sector, eligible private businesses and third sector to obtain PPE from an approved NSS "framework" supplier when their own arrangements failed. Partly as a result of this, and the stresses caused by the state of the global market, a report commissioned by the Scottish Government found, "Scotland's traditional PPE supply routes, just-in-time supply model and PPE stockpiling arrangements were not sufficient in pandemic circumstances" (SG, 2022).

436. In mid-March 2020, Shared Services in Wales expanded its role to supply PPE to primary care providers (including private sector providers) and it also entered into a Service Level Agreement with the Welsh Local Government Association to supply social care settings (Welsh Government statement, INQ000506956, para 178). Following this, Local Authorities in Wales informed the WG and Shared Services of their concerns that PPE supplies would be insufficient to meet the demands of social care settings, a situation exacerbated by updated PPE usage guidance in social care settings on 1 April 2020 (ibid, para 292-5). An Action Plan to address supply of PPE was developed in the summer, with one of the outcomes the implementation of a digital inventory platform, "Stockwatch", which was rolled out to 11 Joint Equipment Stores across the country with the aim of allowing Local Authorities to better serve social care providers (ibid, para 315-16). Although the WG has stated that it is unaware of any cases in which care homes or community care settings ran out of PPE, there has been concern that lack of provision contributed to deaths (Warner, 2021).

437. By September 2020 over-supply was becoming a problem. Between February and July 2020, 32 billion items had been procured at a cost of £12.5 billion (Cabinet Office statement, INQ000497031) but only 2.6 billion distributed (Conn, 2020). According to the Cabinet Office, this was due to: lower demand as RWCS projections had not materialised and clinical and non-clinical interventions had proved effective; "shrinkage" rates (that is, orders which were not fulfilled) were lower than expected; healthcare organisations had managed to procure their own supplies ("leakage"); minimum volumes agreed in contracts with manufacturers; the success of UK manufacturing efforts; and the success of the vaccine roll out (Cabinet Office statement, INQ000497031, para 4.494).

438. Changes to guidance on the frequency of use of PPE had a significant impact on supply chains. Guidance is issued by Public Health England (PHE) and the UK Infection Prevention and Control (IPC) Cell. From February 2020, the UK IPC cell coordinated and

agreed IPC policy for the UK. At a number of points, PHE then published this guidance on behalf of health agencies across the UK. (para 283-284, Susan Hopkins M3 witness statement, INQ000410867)

439. On 17 April 2020, PHE advised that if there were acute shortages, single-use PPE could be re-used (PHE, 2020) in line with WHO guidance. This was subsequently incorporated into the guidance issued by IPC. Re-use, however, was never part of the guidance issued by the health authorities in Wales, Scotland or Northern Ireland (AW, 2021) and it is unclear whether the guidance issued by PHE on 17 April 2020 applied to the DAs. Jointly issued advice on 28 April 2020 by DHSC, Public Health Wales, Public Health Agency Northern Ireland, Health Protection Scotland, PHE and NHSE makes no mention of re-use of single use PPE (PHE, 2020a). During the period what may be termed a "patchwork" of guidance and different expectations across the UK developed.

440. The variance in practice and guidance across England, Scotland, Wales and Northern Ireland made modelling demand difficult at a UK level as re-use reduces the need for re-ordering stocks. Indeed, whatever the official guidance, 'real world' behaviour may not be understood by modellers and procurers. This is problematic, as modellers will be reticent to formally take into account behaviour which breaks guidelines. However, if HCWs have more confidence in consistency of supply, there will be less likelihood that usage protocols will be ignored.

Modelling and forecasting demand challenges

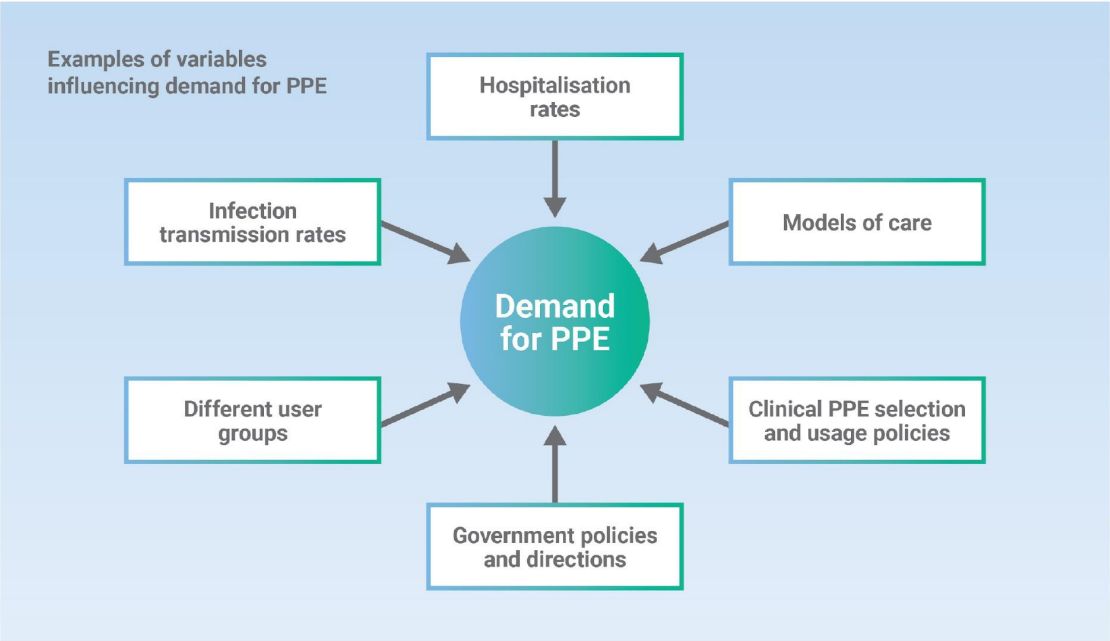
441. During periods of VUCA (Volatility, Uncertainty, Complexity and Ambiguity) modelling and forecasting is particularly challenging. To quote one senior supply chain manager (speaking to me before the Covid-19 pandemic), "All forecasts are wrong. The further into the future you forecast, the wronger [sic] they are. The more precise they are, the more precisely wrong". Whilst said tongue in cheek, there is no doubt that there is some truth in this statement borne out by the experience of the pandemic.

442. Part of the problem of forecasting demand for PPE and healthcare equipment is that it relied on statistical models for the spread of the disease. These in turn were based on estimates of how quickly the infection spread amongst the general population and the level of hospitalisations which would result.

443. The level of infection would also be influenced by government directives as to social distancing; the mandate of facemasks and, more generally, lockdown policies.

444. Figure 27, based on the model used by South Australia Health, shows the various factors which need to be taken into consideration.

Figure 27. Variables influencing demand for PPE



Source: (South Australia Health/Author)

445. Different forecasting models were developed in the early days of the pandemic. Internationally, these include Covid-19 Hospital Impact Model for Epidemics (CHIME) and WHO COVID-19 Essential Supplies Forecasting Tool (COVID-19 ESFT) as well as multiple university/research centre models (see below).

446. In the UK, modelling methodology was adapted by the Scientific Pandemic Influenza group on Modelling (SPIMO) from previous models used to predict the spread of influenza. Even after they had been changed to reflect the observed spread of the virus, however, the government admitted that, "Projections…are especially volatile at times of change (for example, when a wave is turning over) and they cannot predict precise timings or scale of peaks" (DHSC, 2023).

447. Modelling was also made more difficult by other elements of policy. For instance, it was difficult to judge when vaccines would be rolled out; how quickly; the take up amongst the population and, crucially, the effectiveness of the vaccine in preventing hospitalisation.

448. In addition, policy would direct when lockdowns would be lifted, also potentially leading to a spike in the number of people needing hospital care.

449. As the government also commented, "Models do not and cannot predict what is going to happen. They can only illustrate potential futures. Modelling can extrapolate trends based on input data and assumptions, but it is extremely difficult for them to call precisely when growth may turn into decline, and vice versa, as is estimating exactly how high or low that peak or trough might be. There has been substantial pressure, throughout the pandemic, to "predict" what might happen next and so communication that this is not the purpose of modelling has been vital" (DHSC, 2023).

450. The challenges did not stop governments and other organisations attempting to quantify the volume of PPE required.

- WHO COVID-19 Essential Supplies Forecasting Tool (COVID-ESFT) (WHO, 2022) was designed specifically to help governments identify required volumes of PPE by taking into account numbers of healthcare workers per bed; the population of a country and the severity of the symptoms. It provides total quantity and cost per day by PPE type for Covid care and for each type of Healthcare Worker.

- The CDC PPE Burn Rate Calculator developed by the US Centers for Disease Control and Prevention (CDC) calculates the average consumption rate of PPE, thereby providing an estimate of how quickly existing stocks will be depleted. It breaks down demand and remaining inventory by category (CDC, 2023).

- "Worksheet for calculating national PPE need for COVID-19" developed by the Johns Hopkins Bloomberg School of Public Health (2020). This takes into account rates of infection, hospital and ICU admission as well as mortality rates. It sets assumptions for PPE use (e.g. 20 gown changes and 10 masks per ICU patient per day).

451. There are several other University models, but all work on similar methodologies detailed above, variously taking into account populations; admissions (ICU and general); length of stay; "touch points" (HCW/patient contact); spread rates of Covid; specified use of PPE; and types of PPE. They inform orders as well as "burn rates" (depletion). Most of the models applied to hospital settings but some also included community healthcare.

452. In the UK, a further model was developed in March and April 2020 by the DHSC in conjunction with consultancy, McKinsey & Co, forecasting volumes required for various items of PPE (Cabinet Office statement INQ000497031, para 4.237; DHSC statement, INQ000528391, paras 432-438). The DHSC says that the model took a "patient centred approach", by which it meant that assumptions could be made on the volume of PPE which would be used for each patient admitted with Covid-19. These assumptions were then linked to models assessing numbers of Covid-19 cases within the SAGE RWCS to arrive at a total figure of PPE anticipated (DHSC statement, INQ000528391, para 432). The DHSC asserts that within the first two days of being admitted, each patient would trigger demand for 42 sets of general PPE (gloves, aprons, Type IIR mask) and 6 sets of aerosol generating procedures (AGP) PPE (FFP3, gown and gloves). The models provided a daily dashboard; a near-term (7 day) view; and longer term (several months) view of inventory levels based on use of PPE and orders already placed (ibid, paras 435-440) informing the PSC's Buy and UK Make Teams. Given that the model massively over-estimated the amount of PPE that was required, it would be important for DHSC to determine what lessons should be learnt for future pandemics including assumptions on usage and case levels.

453. At a local level, a model was developed by National Institute of Health and Care Research Applied Research Collaboration (PenARC), University of Exeter Researchers and the NHS to predict the demand for in-patient beds, intensive care, PPE, ventilators, oxygen and testing kits. The tool was described as, "being hugely important in informing the

decision-making within both Trusts during the COVID-19 crisis. It has helped us make well-informed and evidence-based decisions across a range of key issues such as PPE and ventilators being available to frontline staff when they need them" (NIHR, 2020).

454. According to an Audit Wales report (AW, 2021), each Health Board in Wales had its own systems to manage stocks and project demand. Attempts were made in April 2020 to develop a centralised model, although challenges were faced in identifying:

- numbers of primary care providers;
- staff numbers;
- treatment sessions; and
- information on independent providers.

455. As with other parts of the UK, guidance and policy was also changing as well as data on the infection rate, hospitalisation rates and length of stays. The final version of Model 1 was ready by late May and was refined in June. A refined second model was in use in August 2020 (AW, 2021).

456. In terms of coordination across the Four Nations, the Scottish Government states that a "4 Country Modelling Group" was established in March 2020 to model the epidemic. The extent to which this informed PPE and procurement policy is not immediately clear. (Scottish Government statement, INQ000498141, para 238)

457. The DHSC set out an aim in September 2020 to achieve stock levels equivalent to 120 days of reasonable worst-case demand for England for a range of PPE products (DHSC, 2020c), for which figures were modelled in November 2020.

458. These categories were:

- aprons;
- body bags;
- clinical waste bags;
- eye protection (goggles and visors);
- FFP3 face masks;
- IIR face masks;
- gloves;
- gowns; and
- chemicals for hand hygiene.

459. Table 4 shows that the stockpiles of these products were all above target, and sometimes many times over the target levels (DHSC, 2021).

Table 4: Volume of PPE in stock on 30 November 2020 and 120-day demand

	Number of items held in stock (millions)	120-day demand (millions)	Stock held as percentage of 120-day demand
Aprons	2.579.0	1,794.0	144%
Body bags	0.3	0.1	221%
Clinical waste bags	60.7	45.0	135%
Eye protectors	812.4	52.0	1,562%
Face mask FFP3	53.0	34.6	153%
Face mask IIR	5,098.1	693.9	735%
Gloves	3,782.1	3,690.0	102%
Gowns	342.9	55.4	618%
Hand hygiene	23.0	7.9	292%

Source: (DHSC, 2021)

460. As highlighted above, given the huge surfeit of PPE products which resulted from over-ordering, either models were inaccurate or ignored. Potential reasons for excess inventory were discussed by Lord Deighton and the Secretary of State for the DHSC on 9 November 2020 (DHSC statement, INQ000528391, para 823) which included:

- lower than expected NHS activity. For example, numbers of face-to-face consultations did not return to pre-pandemic levels as many were undertaken by phone or by video and operations were delayed;
- staff did not follow guidance on usage levels, for instance, re-using PPE;
- additional stock had been ordered to make up for expected failures in delivery and/or quality issues;
- longer term contracts had been entered into to obtain immediate supply and deliveries continued when demand was no longer needed.

In addition to these, other reasons could include:

- sickness levels amongst staff meaning that less PPE was required in practice than in theory;
- many buyers of PPE continuing to use their own sources even when freely available from central stockpiles.

Author recommendation 15

Given the experiences gained from the Covid-19 pandemic, the UK government should work at an international level to produce a single demand model which could be deployed in a future health emergency. Efforts should be made to ensure that relevant data exist which will populate the models. It should not be necessary to develop models from scratch, despite the likely variances in terms of the effects of the disease.

The consequences of policy schemes

Covid-19 Testing

461. Diagnostic testing was a critical element of the UK's Covid-19 response. Testing played an important diagnostic role which helped inform clinical care and infection control strategies in high-risk settings. It also helped monitor the spread of infection across the population as well as assess the efficacy of the roll out of the vaccine programme. From a social and economic perspective, it allowed people to go about their lives and facilitated the re-opening of schools and the hospitality sector.

462. Operation Moonshot, the rapid, mass testing regime introduced in September 2020, was designed, according to Prime Minister Boris Johnson, "to identify people who are negative - who don't have coronavirus and who are not infectious - so we can allow them to behave in a more normal way, in the knowledge they cannot infect anyone else" (BBC, 2020a).

463. The programme was based on Rapid Antigen saliva tests ("Lateral Flow Tests" (LFTs)) that could be undertaken at home, rather than at a testing centre, with results becoming immediately available. Prior to this, standard polymerase chain reaction (PCR) tests had to be sent to a laboratory for processing.

464. There are significant differences between testing device supply chains and those required for PPE equipment, most notably in terms of complexity. Not only are there many more parts required in the assembly of testing devices and kits (approximately 60 parts as opposed to perhaps 5 needed in a mask), but some elements (specifically in the PCR testing process) require cold chain transport and handling to maintain the integrity of the reagents used (UKHSA witness statement, INQ000521972, para 3.36).

465. As research undertaken by Northwestern University stated, "Testing relies on trained personnel with a significant amount of expertise, expensive equipment and complicated logistics that require a stable cold chain. There is a pressing need for testing strategies that are easy to use, reduce labour at the point-of-care, and are inexpensive to deploy anywhere in the world." At that time (2021), the researchers were trialling the use of a freeze-drying process which would allow tests to be stored and distributed as a dry powder and then re-hydrated on demand. They found that this process made the tests "shelf stable" for up to 30 days and in temperatures up to 50 degrees Celsius. This significantly simplifies distribution (Morris, 2021).

466. Ethanol, used in the testing process, is classed as a flammable and combustible liquid. Moving these in small quantities (such as in testing kits) is acceptable under specific regulations, but movements in bulk require compliance with hazardous goods regulations.

467. Another characteristic of the PCR testing supply chain is the "closed reverse loop" aspect. According to the UKHSA, the majority of testing materials (specific reagents and consumables) are manufactured by the companies which also supply the testing machinery (INQ000521972, para 3.36). This means that once the sample has been taken, it must be sent to a specific laboratory, adding a layer of complexity and accuracy to the logistics process. There is also the issue of time sensitivity related to the degradation of the sample. This meant that during the Covid-19 pandemic transport required expedited transport service providers.

468. The mass nature of the testing programme, especially LFTs, relied on the manufacture and shipping of millions of test kits, made almost exclusively in China and shipped by air cargo. This included a $1,635,000 contract with broker Air Charter Service Ltd (ACS) in September 2020 for the movement of freight under the heading "The Provision of Freight Services for the Supply of Lateral Flow Test Kits for Testing of Covid-19" (OJEU, 2020). The tender document elaborated on the contract stating, "The supply of these new test kits is currently limited in the face of very high global demand and consequently it was necessary to contract for supply on an ex-works basis for product manufactured in China in order to secure the required quantity of product and prevent gazumping" (OJEU, 2020).

469. The tender also provides some interesting background, as it states that when goods are sold on an ex-works basis (see glossary for explanation), there is a risk that the goods could be sold to a higher bidder, indicating a lack of trust or reliability in the supply chain (OJEU, 2020).

470. The critical nature of the shipments to support the testing programme meant that air freight (rather than cheaper but slower sea freight) was regarded as the only option. The kits were flown from Xiamen, China to Doncaster Airport. Over £76m was spent in total on air movements of lateral flow tests, most being spent with ACS although a small proportion was also allocated to Virgin Atlantic.

471. In January 2022, a British manufacturer of LFD tests, SureScreen Diagnostics was approved by the UK government. The company took six months to gain approval, a timescale which raised questions given the shortages of the tests at the time. The tests were distributed from the manufacturer's central warehouse in Nottingham to national distribution centres supplying the NHS, pharmacies and other channels. SureScreen reportedly grew from 50 employees pre-pandemic to around 600, increasing its capacity and producing a million tests a day by 2022 (Johnson, 2022).

<u>The "Parallel Supply Chain"</u>

472. As already detailed, the distribution channels which had been established by the UK government and DAs were unable to meet the dramatically changing supply and demand needs created by the Covid-19 pandemic.

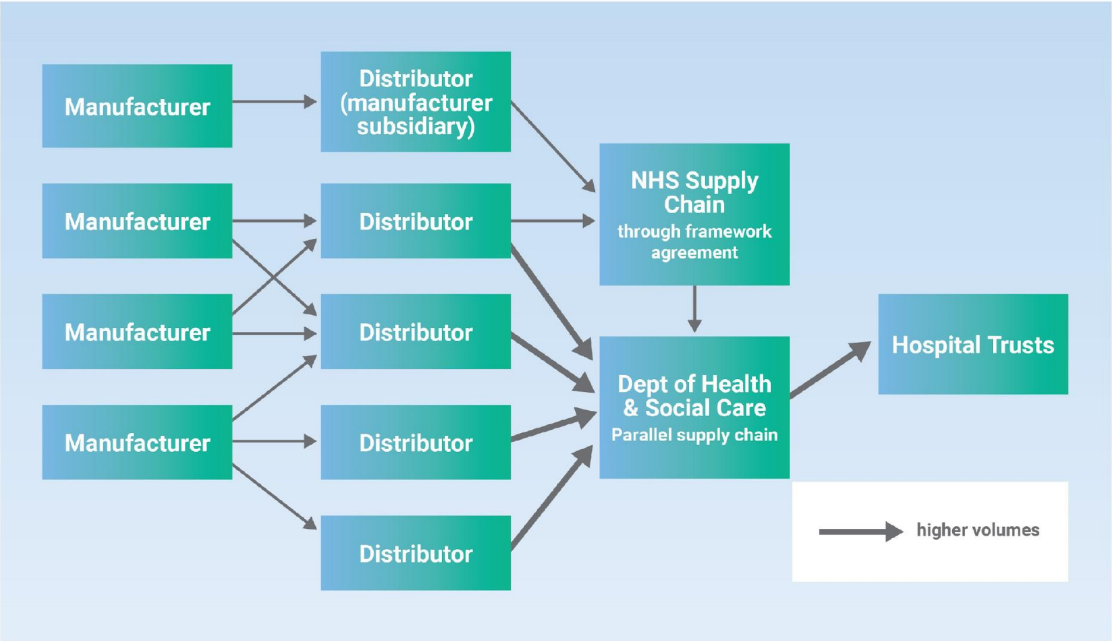
473. Not only did demand for PPE increase overall but there was a need to:

- source new suppliers;
- identify and integrate into supply chains manufacturers which had never made PPE and health equipment before; and
- extend the distribution of PPE to social care providers.

474. Consequently, a new supply chain structure was developed by the DHSC called the "Parallel Supply Chain" (PSC) headed by Lord Deighton (Cabinet Office statement, INQ000497031).

475. The Boardman Report claims that over the years before the pandemic, a framework had been constructed by the UK government which pushed most of the risk for supply and quality of PPE and healthcare equipment onto a small number of suppliers (which may or may not have their own manufacturing capabilities) (Boardman, 2020). This strategy made sense economically, but it also resulted in lower levels of supply chain visibility beyond the major Tier 1 suppliers. One of the aims of the Parallel Supply Chain was to re-establish direct links with upstream suppliers (including manufacturers), as well as create downstream distribution channels linking new health and social care settings which had not been supplied before.

Figure 28. The "Parallel Supply Chain" developed by the DHSC



Source: (MSHR/Author)

476. The PSC became operational at the beginning of April 2020 and received 25,000 offers of support from 15,000 suppliers in response to the government's request for new suppliers (Cabinet Office statement, INQ000497031, para 1.29). It was responsible for managing the "High Priority Lane" as well as an "ordinary lane" to assess leads. 450 staff were employed in the "Buy" function of the PSC in June 2020 (ibid., para 4.320).

477. Other roles of the PSC included:

- supply chain planning in terms of volumes and type of PPE required;
- dealing with UK manufacturers forming part of the "Make" programme;
- sourcing new suppliers, in particular those based in China, using the British Embassy in Beijing as well as undertaking a level of due diligence;
- checking orders against PPE specifications in line with MHRA guidance and approval and quarantining shipments which failed to meet requirements; and
- take receipt, warehouse and distribute shipments of PPE to downstream supply chain partners, including the procurement organisations of the DAs, LRFs, wholesalers, primary health organisations as well as Trusts (ibid. para 4.301).

478. The activities of the British Embassy in Beijing are worthy of note. At the end of April 2020, 200 staff were working on procurement with various teams dedicated to different functions and types of PPE and healthcare equipment products ranging from ventilators and ventilator components to masks and gloves (Former DIT statement, INQ000527714, para 13.7). As of 23 April 2020, the team had supported DHSC procurement of £330 million of which £280 million related to PPE and the rest to ventilators, ventilator components and pumps (ibid, para 13.49).

479. PSC's warehouse function was out-sourced to Clipper Logistics, sub-contracting to NHS SC's existing logistics operator, Unipart (SCCL statement, INQ000492085, para 5.17,) whilst final delivery was undertaken by a range of private delivery companies (CO statement, INQ000497031, para 4.511).

480. Clipper's role initially involved the establishment of a transport and warehousing network to supply 250 product lines of PPE to between 400-500 hospitals (GXO Logistics statement, INQ000553497, para 14). The logistics supplier was able to set up the necessary structures, including IT systems and a 200,000 sq ft warehouse in Daventry, in five days, and commenced operations on 3 April 2020 (ibid, para 27). According to the company, such an effort would normally have taken 10-12 weeks (ibid, para 27). From mid-March onwards, distribution was extended to primary health and care home settings in collaboration with digital platform provider, e-Bay. Clipper's role was to pick and pack boxes ordered over the new e-Portal and arrange deliveries, a large proportion of which were handled by Royal Mail (ibid, para 29).

481. The value of the contracts awarded to Clipper Logistics between March 2020 and June 2022 amounted to £198,317,195, with costs rising throughout the period due to additional distribution centres being added to the network to cope with the volume of PPE being procured (ibid, 33-34). Clipper was contracted on an "open book" basis, meaning that its operating expenses were passed on directly to the customer (Unipart and ultimately SSCL) in addition to a management fee. In this case, the management fee was 4% of the total costs which, in GXO Logistics' witness statement, Antony Mannix, formerly Chief Executive Office of Clipper Logistics, describes as a "standard percentage fee" (ibid, para 36). I believe this to be the case and in my professional experience I have knowledge of

similar contracts with fees ranging between 2.5-5% depending on individual circumstances.

482. At the beginning of the crisis, PSC had no visibility of the demand for PPE or the existing stocks held by the Trusts and so undertook deliveries on a push basis, working to their own estimates. From May 2020 onwards, it was supplied with data on inventory holdings by the individual Trusts which were then used as a basis for delivery volumes.

483. The establishment of the PSC was not without criticism as there were assertions that the new purchasing organisation was employing an overly-bureaucratic approach, managed by accountants (specifically consultancy company Deloitte) rather than a more proactive solution to finding suppliers and sourcing goods.

484. The British Medical Association (BMA), commenting on the role of private sector companies in the PSC said, "Delegating large parts of the management of procurement processes and supply chains to a complex web of external companies has arguably left the Westminster government less able to respond in an agile and rapid way to the dramatic increase in demand for PPE caused by the pandemic" (BMA, 2020).

485. It has been suggested that the PSC ignored many smaller businesses, often lower tier suppliers, in favour of bigger brands, often overseas. One expert in the UK textile industry, Kate Hills, commented, "The people who can make this PPE are not well-known names, they are contract manufacturers behind the scenes. They've filled in the government's request forms and heard nothing back" (Davies, 2020). She went on to say that a better approach would have been to proactively work with many of the smaller manufacturers which make up the UK textile industry to re-build a domestic supply chain "from scratch".

486. The problems of the slow and confused central approach, meant that many healthcare providers went back to trying to source their own supplies of PPE, in some cases using local manufacturers which had offered their services. As the number of new infections and hospitalisations slowed, gradually pressure on supplies was relieved.

487. The PSC had a huge budget so it is not surprising that it had success in procuring large amounts of PPE on the global market. This translated into increasing inventory levels as the year progressed. However, its challenges have been well-documented:

- a considerable proportion of equipment was below standard and had to be rejected, such as allegedly non-sterile gowns (Conn, 2023);
- a lack of knowledge of PPE market led to purchase of non-compliant products such as face masks with ear loops rather than head straps (Cabinet Office statement, INQ000497031, para 1.27);
- despite guidance stating contracts should be short-term to adapt to changing market conditions, the PSC found it difficult to re-negotiate terms due to the market conditions (Cabinet Office statement, INQ000497031, 1.26);
- contractual prices were 'locked in' at the top of the market with shipments not received until after the peak of the crisis. For example, one contract seen by the author (dated 27 April 2020) involved an agreed price (£14,280,000) for the delivery of gowns in 9 separate consignments between 3 May and 28 June

(volumes redacted) with a deposit of 50% of the order paid at Contract Award. According to Shared Services Wales (AW, 2021) the price of a gown had already fallen to £2.50 in May 2020 from £4.50 in April 2020;

- local offers of help were ignored (Buchan and Ng, 2020); and
- huge quantities of PPE continued to be delivered after the worst of the pandemic was over (Ironmonger, 2024).

Author recommendation 16

Establishing the Parallel Supply Chain as a completely new distribution organisation in a pandemic to centralise procurement and supply as well as provide logistics capacity was a massive challenge and should not be repeated in a future healthcare emergency. Whilst reverting to pre-Covid-19 structures in a "business as usual" environment may have seemed a sensible decision, there is no reason to believe that existing organisations will perform more effectively in the event of a new pandemic. New infrastructure must be put in place which can function as well in a pandemic as it can under normal market conditions. Suggestions for how this can be achieved are outlined below.

Schemes to secure supplies from domestic manufacturers

The Ventilator Challenge

488. In March 2020, there were fears that hospitals would run out of sufficient ventilator capacity within a matter of weeks. The "Ventilator Challenge" was initiated by the UK Government, encouraging the private sector to help meet the needs of the NHS in the design and production of ventilators. The aim was to make 30,000 ventilators in eight weeks (the NHS already had up to 8,000 ventilators in operation across the UK) (Cabinet Office statement, INQ000497031, para 4.3).

489. The challenges included:

- designing parts to meet existing specifications;
- working with multiple suppliers, many of which had no experience of manufacturing healthcare equipment, let alone ventilators;
- putting the products through clinical trials;
- gaining regulatory approval;
- re-opening factories closed due to Covid-19;
- coordinating supply chains involving millions of parts from multiple countries;
- distributing the ventilators to hospitals in line with demand; and
- training staff in their use (PA, 2024).

490. The lead consultancy working on the project was PA Consulting. It commented, "We had to look at thousands of different components across the different devices, figure out where we could get them and where there might be an international shortage" (PA, 2024). In this respect, the ventilator parts market faced the same sort of global competition as PPE products. This situation was complicated by the fact that the fifteen UK designs shortlisted in the "Ventilator Challenge" were often competing for the same components.

491. Transport management and provision could be undertaken on an ad hoc basis in response to events, rather than in a planned manner. PA Consulting mentions that at one point, during a holiday, a fleet of vans was chartered to move batteries across the border from southern China to Hong Kong.

492. At the end of the process, 3 designs (out of 12) were approved by the MHRA to go into production, issuing EUAs to Penlon Ltd on 15 April 2020; to Smiths Medical (Parapac Plus P300) (for production of the ventilator at two sites not covered by existing approval certification) on 27 May 2020 and for the University College London Ventura device on 2 April 2020 (MHRA statement, INQXXXXXXXXX, paras 126-128). The Cabinet Office also supported the scaling up of the production of already approved Vivo65 and the Nippy4+ ventilators produced by Swedish Breas Medical (Cabinet Office, 2020).

493. Whilst forecasts had suggested that there would be a requirement for 30,000 ventilators, at the peak only 13,000 were actually needed. The original target was reduced in April to 18,000 leaving a surfeit of parts which had already been procured. Changing understanding of the disease also led to evolving specifications and this influenced the numbers and type of ventilators required (Davies, 2020).

494. Many of the additional ventilators which were sourced came from China (many sourced by the British Embassy in Beijing) rather than the UK. As with PPE, in some cases there were quality control issues leading to the rejection of a shipment of 250 ventilators which were considered unsafe (Davies, 2020).

495. There has been criticism that it would have been far more effective for efforts to have been focused on the scaling up of existing designs than asking for assistance from manufacturers which had no prior experience of producing a highly technical piece of equipment. As a report examining a similar "challenge" in the USA stated, "Ventilators were made by Fitbit, Virgin, NASA, and Dyson. But expertise in wearables, flight, and vacuum technology did not translate well to development of a life-support device" (Branson, 2023). The help of large manufacturers, such as Dyson, may well have been better focused on sourcing specialised components for existing ventilator manufacturers than trying to build their own versions from scratch. Also, it would have seemed more practical to produce ventilators from designs under licence from existing manufacturers than trying to design new equipment. As the MHRA stated, two of the designs it approved during the first wave of Covid-19 were developed by existing medical device manufacturers, one of which just needed approval to produce ventilators at new sites. The third required approval for a design based on an existing anaesthetic machine (MHRA statement, INQXXXXXXXXX, paras 156-157).

Author recommendation 17

If new healthcare equipment is required as part of pandemic response, efforts should be focused on providing existing medical equipment manufacturers with the resources to scale up production rather than encouraging designs from manufacturers with no relevant experience. Production under licence should be a consideration.

The "UK Make" programme

496. UK Make was the programme established under Lord Deighton to source PPE from UK sources when it became clear that existing stockpiles would not be sufficient to meet needs and sourcing products on the global market was proving problematic. In many respects it was successful. According to the UK Government, between 1 December 2020 and 28 February 2021, 82% of the demand for PPE was being met by UK manufacturers (DHSC, 2021b). This was a major change from the beginning of the pandemic when almost all PPE was imported. Of all the PPE categories only gloves had no production capabilities in the UK.

497. Table 5 shows that by end of February 2021, UK manufacturers were producing more PPE than forecasted demand in the categories for aprons, clinical waste bags, and facemask FFP3.

498. The vast majority of this new capacity came about due to "re-purposing" existing, related production. For example, four manufacturers, Elite, Polystar, PFF (see below) and Lincoln, were able to pivot from producing plastic bags to plastic aprons.

Table 5: UK-made items of PPE, compared to expected demand for the 3 months 1 December 2020 to 28 February 2021

Category of PPE	Expected demand for PPE (millions, except body bags)	Supply of UK-made products (millions)	Supply of UK-made products, capped at 100% of demand (millions)	UK-made PPE (capped) as percentage of demand
Aprons	497.1	591.2	497.1	100%
Body bags	25,000.0	0.0	0.0	0%
Clinical waste bags	10.9	32.3	10.9	100%
Eye protectors	27.8	25.4	25.4	91%
Face mask FFP3	17.4	18.0	17.4	100%
Face mask IIR	470.0	292.7	292.7	62%
Gowns	14.1	5.2	5.2	37%
Hand hygiene	2.8	2.1	2.1	73%
Total	1,040.1	966.9	850.8	82%

Source: (DHSC, 2021b)

499. Other examples include:

- Honeywell establishing a production line at its Motherwell factory to make more than 65 million FFP2 and FFP3 respirators;
- Survitec, an existing producer of safety related equipment in Birkenhead, contracted to make gowns;
- PFF invested £1 million to purchase machinery capable of producing disposable aprons;
- Aston Martin in conjunction with Multimatic designed and built a tool which allowed Perspex to be made in one piece. It also worked on 3D printing technology for protective visors;
- CNF Precision Engineering switched to the production of ventilator parts;
- ICL Tech, a plastics thermoforming fabrication company, repurposed its operations to medical visors;
- AE Aerospace produced 6,000 parts for ventilators;

- BAE Systems used 3D printing technology to make face shield components;
- Alderman's Drinks switched from production of spirits to manufacturing hand sanitiser;
- AMTICO, a flooring manufacturer, modified its processes to make headbands for face shields; and
- High end clothing manufacturer, Barbour, supplied gowns and other items of PPE.

500. Whilst showing the willingness and success of pivoting manufacturing to PPE and healthcare equipment, this was very much a short term solution underpinned by:

- the high price of PPE at that time;
- the desire to keep production facilities operational rather than furloughing staff; and
- the goodwill of businesses looking to "do their bit".

501. Whilst there does not appear to be any hard data, it is very likely that the majority of those businesses which pivoted to the manufacture of PPE and healthcare equipment, have subsequently returned to their former line of business. All the examples cited above involve high value, specialist manufacturing companies which would not normally be interested in commodities such as PPE. This is a problem for the government when looking at long term resilience plans.

502. As one executive for a company which pivoted to PPE production during the pandemic said, "The landscape of procurement has returned to pre-Covid practices and it's clear that lessons haven't been learnt. This puts domestic capability at serious risk of vanishing, and when, not if, another pandemic hits, I fear the country will be in the same predicament it was when Covid first hit, a frantic scramble to procure life saving PPE and loss of life when it could have easily been avoided" (Parks, 2023).

503. Of the 76 approved suppliers presently in the Single Use Personal Protective Equipment and Medical Protective Consumables framework of NHS Supply Chain, 23 form part of UK Make. This does not reveal, however, the volumes sourced from the UK and this would be a key question, four years after its initiation.

504. In Lord Deighton's report (DHSC, 2020c) it was asserted that international PPE suppliers were building factories in the UK. The example in his report was Medicom, a Canadian-based mask manufacturer, which established a factory in Northampton creating 250 jobs. This seems to be a success story and the company has also invested in glove manufacturing in France. It manufactures under a long term contract with the UK government, supplied with high-tech meltblown nonwovens material by the UK production facility of Berry Global, a line in which the supplier has specifically invested in to support the contract.

Author recommendation 18

"Blueprints" should be developed, in conjunction with industry associations, which allow UK domestic PPE and healthcare equipment supply chains to be swiftly initiated in the event of a pandemic. This would involve establishing lists of pre-qualified suppliers, creating relationships and formal lines of communications between government, healthcare equipment procurers and business.

Critical Engineering Requirement Team in Wales

505. The Critical Equipment Requirement Engineering Team (CERET) was established by the Welsh Government (WG) and Industry Wales (a WG Arm's Length Trade Body supporting manufacturing in Wales) in conjunction with local businesses and academia to review sourcing offers of PPE in conjunction with NHS Wales Shared Services Partnership.

506. A "mailbox" was established by the Welsh government for offers of help. The system allowed small and medium-sized businesses which were not previously recognised as suppliers to the WG to work with larger companies which had undergone the compliance process.

507. 30 businesses were able to pivot production to the manufacture of hand sanitiser, 25 produced face visors and others invested in equipment which would allow the mass production of facemasks. One example of this is the manufacturer, RotoMedical, based in South Wales, which partnered with a distributor Lyreco, an already established supplier to the National Procurement Service (NPS). This allowed RotoMedical to supply facemasks to Welsh schools through Lyreco's distribution network (Audit Wales, 2021).

508. Audit Wales found that CERET enabled some Welsh businesses to build capacity and achieve certification for their products. However, the time this process took meant that manufacturers missed out on the peak of the market prices in spring and summer 2020 when they would have been more price competitive (ibid).

Section 6: Supply chains post-pandemic

Section Summary

Since the Covid-19 pandemic, there have been numerous initiatives undertaken by the UK and DA governments, as well as by procurement and supply organisations, to improve supply chain efficiencies. Technology has been a major focus and there has been investment in inventory management systems at a local and national level. It is yet to be seen how effective the largest of these, a multi-year, £330 million contract with Palantir, will be.

In England, NHS SC has taken steps to build more confidence amongst its customer base and is investing in more capacity as well as improving communication. However, without root and branch re-structuring it is difficult to see how much more resilient the PPE and healthcare supply chain will be in the event of a new pandemic.

The Scottish government believes greater levels of centralised procurement for all related public organisations on a national basis is the best solution. Despite this, centralisation is not a panacea, as evidenced by the reluctance of NHS Trusts to use NHS SC in England for all their needs. New thinking and smart solutions are required, such as rotating and virtual inventory held by manufacturers, direct-to-consumer (DTC) or vendor managed inventory (VMI) models, combined with a UK-wide approach to inventory visibility and a government agency with overall responsibility. Investment in advanced automation would also help to stimulate a UK manufacturing sector, a critical part of any supply chain resilience response.

Improving supply chain management during a pandemic

509. The performance of healthcare equipment supply chains during a pandemic will be improved by developing a range of responses rather than fostering reliance on any one element. It will rely on a combination of "robustness" and "resilience" discussed earlier; "robustness" being the ability to resist value-destroying change and "resilience" being the speed with which a supply chain can return to its previous state ("bouncebackability").

510. Since the start of the pandemic, the importance of supply chain resilience has been recognised by the UK Government. Project Defend, undertaken by the DIT to review supply chain vulnerabilities, has now developed into a standing Directorate, the Economic Security and Supply Chain Resilience Directorate (ESSCR). One of its aims is to build capability across critical sectors through developing guidance on critical imports and supply chain resilience. This includes Horizon Scanning to identify possible disruptive events (Former DIT statement, INQ000527714, para 12.1-6). It should be recognised that this Directorate looks at a range of supply chains and the level of resource dedicated to PPE and healthcare equipment is unclear.

<u>Stockpiles</u>

511. Looking at the challenge through this lens, stockpiling of products is an obvious measure to increase supply chain robustness. It would ensure the flow of PPE and healthcare equipment to healthcare workers in the early stages of a pandemic. The stockpile would

need to be fit for purpose and "smart", an issue already discussed but which will be summarised later in this section.

512. A critical point to note is that high levels of inventory do not correspond with availability of stock. This has been shown in numerous examples relating to PPE and healthcare equipment where inventory has been disposed of due to passed expiry dates. There is also the issue of having the wrong stock for the crisis. The stockpile needs to be "pandemic neutral", meaning that it needs to hold appropriate levels of PPE whatever levels and types of protection are required by HCWs, decisions informed by the up to date advice of epidemiologists and experts in infection prevention and control.

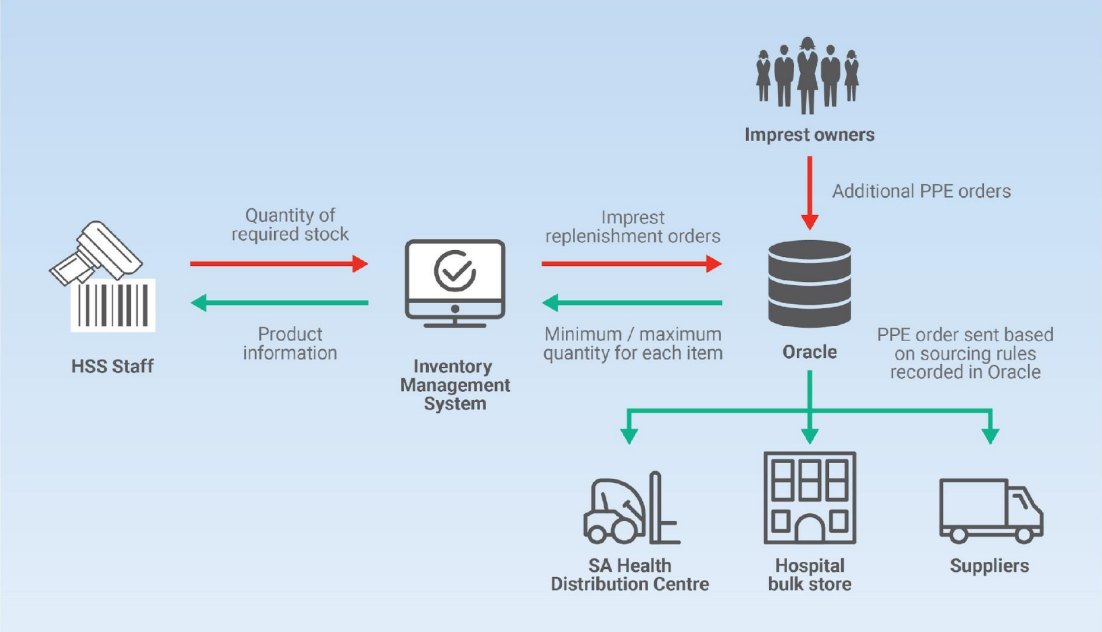
Technology

513. Technology will play an important part in achieving this goal as it will provide visibility of stock, wherever it is being stored, including use-by dates, stock keeping units (see glossary) and volumes.

514. The system used by the state of South Australia's health organisation provides a good benchmark. It uses the enterprise-wide Inventory Management System (IMS) of software company, Oracle, in conjunction with a specific application for local stocks kept in hospital and even in ward-level stores ("imprests"). The Oracle system includes the following management functions:

- receiving items at the distribution centre and bulk stores from suppliers;
- recording minimum and maximum quantities of inventory for each location (distribution facilities and hospital stores);
- recording product information;
- replenishing inventory;
- producing slips for use by staff to pick products from the warehouse and dispatch to the required location; and
- recording the shipping and movement of inventory from the distribution centre to the bulk stores and local hospital/ward stores (AGD, 2022).

Figure 29. Inventory Management System processes employed by South Australia Health



Source: (South Australia Health/Author)

515. In the UK, a specialised hospital logistics application, StockWatch, was developed in June 2020. It helped digitalise PPE and healthcare equipment inventory records held by NHS Trusts with the developer asserting, "most NHS Trusts were using Excel spreadsheets with inconsistent data to track PPE logistics". Their website claims, "public service providers can see how much stock they have left, how long it will last them based on past usage, what they need to get more of, and where other organisations might have additional stock that they can use." The application was adopted by 70 NHS Trusts, social services, mental health services, ambulances and GP surgeries (MedTech News, 2020).

516. During the Covid-19 pandemic, NHS England used a software system, Foundry, developed by US technology company, Palantir, to manage the order, storage and distribution of supplies of vaccines and syringes to vaccination centres. This provided a real time view of vaccine take up across England as well as automated reporting to all stakeholders (Palantir, 2024). This relationship has developed and Palantir won a contract in 2023 to transition data from a diverse range of NHS systems (not just inventory) onto a "Federated Data Platform (FDP)". According to NHS England, the FDP will enable, "NHS organisations to bring together operational data – currently stored in separate systems – to support staff to access the information they need in one safe and secure environment. This could be the number of beds in a hospital, the size of waiting lists for elective care services, or the availability of medical supplies" (NHS England, 2024).

517. The contract to operate the FDP was then fully awarded to Palantir with support from the consultancy firm, Accenture, in 2023 and is worth £330 million over seven years. Supply chain data will be one of the five "use cases" of the new system and it will be important to

review how this contract develops in terms of its application to PPE and healthcare equipment.

518. Technology can also be used to address the challenges of managing centralised inventory. Latest warehouse management systems mean that inventory does not necessarily have to be held in a centralised facility but dispersed around the country at locations from where it can be more readily deployed.

519. A "virtual stockpile" will need visibility to be extended to suppliers' warehousing and supply chains. This will involve NHS Supply Chain using its leverage as a major customer to drive through innovations. How this works is discussed later in the section.

Diversified supplier base

520. Resilience ("bouncebackability") relates to the speed in which the stockpile can be replenished as well as the reliability of supply. To mitigate risk (especially extreme during a pandemic when there is global competition for supplies of PPE), the supply base will need to be diversified, including UK, friend-sourced, near-sourced and far-shored suppliers.

521. The diverse supplier base will include a mix of distributors and manufacturers. Direct relationships with the latter will be essential to mitigate bottlenecks of production and understand problems before they impact on the supply chain.

522. This may have cost implications. Distributors are often able to use their buying power, created by leveraging demand from multiple customers, to achieve economies of scale. Working directly with manufacturers may lead to higher unit costs.

523. The pandemic response showed that scaling up production was only really practicable with existing suppliers which had existing capabilities. It took a long time for new suppliers to develop products, gain regulatory approval and then start production. In reality, the critical shortage of PPE lasted a relatively short period of time, from April to May 2020. Consequently, the response by manufacturers to fill any gaps in inventory requirements needs to be measured in days rather than weeks and relationships and capacity need to be already in place.

524. The role of PPE and healthcare emergency equipment stockpiles will be critical to supplying healthcare providers between the time that "business as usual" stocks are run down and UK JIT manufacturing starts up. In turn, JIT manufacturing will bridge the gap between the exhaustion of the emergency stockpile and the normalisation of the market when supply returns from off-shored global manufacturers.

The UK's healthcare supply chain resilience since the pandemic

525. Since the pandemic there has been continued coordination between the Four Nations to review and refresh the UK Influenza Pandemic Preparedness Strategy 2011. To ensure that the right countermeasures are in place, this has been broadened to a Pandemic Flu Response Plan (PFRP) (WG, 2024) although details of the plan and how it differs from the PIPP are not yet readily available.

Changes introduced by the UK government in England

526. The emergency arrangements put in place to manage the supply of PPE and other healthcare equipment changed on 1 April, 2022 when responsibility for much of the supply reverted back to NHS Supply Chain from the DHSC. According to the NHS Confederation, "The priority is always to drive continuity of supply, particularly as we navigate a challenging period for global supply chains" (NHSSC, 2022). In light of the disruption to supplies experienced during the Covid-19 pandemic, it is worth highlighting that the element of "cost", in absence of mention, seems of a lower consideration.

527. Increased stockholding has been one of the priorities of NHS Supply Chain since the pandemic. In September 2022, it stated that it had 130,000 pallets of PPE in storage, amounting to 7 weeks cover. Due to the huge quantities of inventory which had been ordered, cover for some items quickly became much longer and disposal to reduce storage costs became necessary.

528. Following on from the Boardman inquiry, NHS Supply Chain claims that it has put in place the following actions to increase the resilience of its supply chains by:

- determining the country of origin of manufacture of products, enabling potential supply disruptions to be identified as early as possible;
- prioritising the mapping of suppliers' product categories that form part of the top 80% of sales, alongside embedding the requirement into future procurement exercises; and
- implementation of risk-based analysis tools to provide analysis of labour standards and modern slavery (NHSSC, 2022).

529. These exercises are intended to increase visibility within the supply chain and mitigate the impact of any unexpected events (political, economic, societal, technological, legal or environmental) which could disrupt supply. Assessing the progress of the implementation of the recommendations will be important to judging improvements in supply chain resilience. Whilst determining the countries in which suppliers are based is a first step, ideally the entire supply chain should be mapped, at least for the most important product categories, down to lower tier supplier level in order to guard against sole supplier dependence.

530. Specifically, NHS Supply Chain has acquired a new eProcurement system and a risk management tool from NQC Ltd which enables it to map risk throughout its supply chain. Suppliers provide the tool with information which gives NHS Supply Chain more in-depth views of suppliers' supply chains as well as second and third tier sub-contractors.

531. In addition to the above, European legislation (Corporate Sustainability Due Diligence Directive (CSDDD)) passed in 2024 requires large companies operating in Europe to fully audit upstream supply chain partners from an ethical and environmental perspective: manufacturers must "know their suppliers". This will increase the visibility of supply chains overall with wider benefits in terms of resilience. As many of the manufacturers operating in Europe also supply the UK market, this enhanced visibility should also be available to UK healthcare providers.

532. This level of upstream supply chain visibility will be crucial to identifying potential disruption and bottlenecks to supply. However, it will need to be combined with a 'control tower' capability, managed proactively by a team of supply chain professionals who can interpret the data and make pre-emptive decisions. It is not clear if this function exists or, if it does, how it is managed and operated.

533. Improved channels of communication have been established. NHS Supply Chain "Voice of the Customer" groups meet monthly. They include representatives from NHS Supply Chain, Clipper (a logistics service provider), the DHSC, and Regional PPE Leads customers. The acute, non-acute and regional leads PPE groups help:

- identify and communicate supply chain challenges and specific disruption to products;
- provide early warning of shortages to customers;
- discuss and mitigate pricing challenges;
- foster an understanding of demand management during shortages; and
- identify alternative products, if necessary.

534. NHS SC clinical staff from each category tower, product assurance, resilience and Clinical Nurse Advisory Teams meet weekly in the Clinical Procurement Support Network (CPSN) to discuss issues which may impact supply.

535. Much of the communication put out by NHS SC has been focused on building greater levels of trust with NHS Trusts. Part of the reason for this is to encourage more Trusts to buy their supplies through NHS SC by demonstrating the increased levels of resilience which using its supply chain tools and purchasing power can bring about.

536. The DHSC's e-Portal closed on 31 March 2024 and all orders now revert to NHS SC. However, the DHSC claims it has the operational capability to stand ordering platforms back up if required in the event of a new pandemic. It is unclear how its ordering application has been "mothballed" and what it would take to re-instate if an alternative distribution channel for primary healthcare providers was required once again in a future pandemic.

537. NHS Supply Chain's policy of using more UK manufacturers seems to be being put into action. For a recent award of its plastic apron framework contracts, four of the eight suppliers were manufacturers with factories in the UK.

538. Although these arrangements may help maintain a UK manufacturing base of PPE and other healthcare equipment, it is unclear how quickly production could be scaled up. Outside of the companies identified in the framework, it is also unclear which other manufacturers exist to provide capacity if required in a new pandemic.

<u>Will PPE supply chain resilience continue to improve?</u>

539. There is no doubt that there have been improvements in the resilience of PPE supply chain structures since the Covid-19 pandemic. It is almost unthinkable that lessons would

not have been learnt from such a crisis which revealed such levels of systemic weakness. It is evident that there have been efforts to:

- improve communication between NHS Supply Chain and its customers;
- set stock levels at more appropriate levels;
- encourage UK manufacturing through inclusion in Framework agreements.

540. NHS SC has been directed by DHSC to encourage Trusts to adopt inventory management systems (IMSs) which will also provide more visibility.

541. Risk management tools have been introduced which will provide early warning of potential disruption to supply. There is also more awareness of the risk presented by over reliance on suppliers based in markets governed by adversarial or hostile administrations.

542. However, a key question will be whether this focus on supply chain resilience will remain in, say, five years' time when memories of the Covid-19 pandemic are not so vivid. Resilience comes at a cost – and government priorities and pressures often result in cost cutting due to competing political and financial priorities. It must be recognised that although many of the individual measures required to bring about supply chain resilience may seem more expensive, they will be insignificant in comparison to the costs of ensuring supply of PPE and healthcare equipment during the next pandemic if no mitigating steps are taken.

543. In my view, unless the UK government implements plans to:

- establish an overarching Control Tower approach to supply chain management;
- initiate virtual, rotating stockpiles to address the problems of PPE stock control;
- develop a domestic UK PPE supply chain;
- adopt diverse sourcing strategies such as near-sourcing or ally-shoring;
- implement healthcare community-wide inventory visibility systems; and
- rationalise the complex procurement environment,

544. it is doubtful whether supply chains will be made sufficiently resilient to stand another shock such as the Covid-19 pandemic. What these points mean in practice is explained in more detail below.

545. Undoubtedly introducing a more sophisticated supply chain resilience strategy, including the points highlighted above, would have an impact on costs. But they should be regarded as an "insurance policy" against future disruption and, in the same respect, compared with the billions of pounds which could result from reverting to the PPE and healthcare equipment inventory policy in place before the Covid-19 pandemic. As already stressed, bigger inventories do not necessarily mean more resilience as there are costs involved in making sure that the stockpiles are fit-for-purpose. It is recommended that any future research project undertaken by the government should identify and carefully balance the costs of all these alternative inventory and supply chain strategies.

Future PPE and healthcare equipment supply chains in Scotland

546. Lack of PPE and healthcare equipment inventory visibility during the pandemic was identified by the Scottish Government as a clear vulnerability. Whilst NSS had knowledge of national stock levels, it did not have access to data for Health Board inventory held at local department/ward levels. NSS now claims that this lack of visibility has been addressed through a new IMS providing data on stock at local and national levels (NSS statement, INQ000521969, para 137). Additionally, National Procurement has invested in new large capacity warehouses (ibid, 285).

547. In terms of forecasting usage and demand, National Procurement has implemented a new planning solution and uses dashboards to track and report PPE usage as part of more system-based processes (ibid, 288-289). As in England, it also undertakes supply chain mapping of origins of all procured products, working with the DHSC to identify risks and has a system in place to identify alternative products if a supplier faces disruption (ibid, para 307).

548. Following the pandemic, the Scottish Government undertook a consultation exercise to review a number of options looking at how PPE and healthcare equipment supply could be improved, both during "business-as-usual" times and during health emergencies.

549. The premise of the Scottish Government was that existing arrangements did not meet the needs of the Scottish healthcare system and that only action on a national basis during the pandemic had prevented supplies running out.

550. The consultation exercise set out to identify the best way in which a "PPE Futures Programme" could be implemented resulting in:

- a resilient supply chain;
- high quality product at an appropriate price; and
- best value in PPE buying.

551. The options included:

1. A continuation of the Four Nations approach to pandemic countermeasures;
2. As A. but including a Scotland-only PPE pandemic stockpile procured and managed by NSS which would also manage a "surge" capacity contract;
3. Move away from a Four Nation approach. In addition to an NSS procured and managed pandemic stockpile, include an element of joined-up public sector buying and develop local supply chains; and
4. Develop a strategic Scotland-led pandemic focus at the same time which would involve NSS taking on the entire responsibility for the procurement and management of a pandemic stockpile, surge capacity as well as buying and supplying the entirety of the Scottish public sector with PPE and healthcare equipment.

552. At the outset of the consultation, the Scottish government recommended that Option D was, "by a clear margin, the most likely to achieve the Programme's objectives" (SG, 2022).

553. It seemed that the majority of those taking part in the consultation agreed:

- 80% thought that Scotland should have its own pandemic stockpile;
- 79% said that private health and social care should be supported by the Scottish government, including gaining access to the stockpile; and
- 45% indicated that their organisation would take part in collaborative buying approach (SG, 2022).

554. One important issue highlighted by the consultation (with relevance right across the Four Nations) is the view that the provision of PPE and healthcare equipment to Primary and Social Care providers should receive the same level of priority as hospitals. One fear raised was that whilst budgets could be pooled for procurement, this did not guarantee equal treatment in terms of supply during a pandemic (SG, 2022a).

555. At present, it is unclear whether these proposals will be put into practice or the timescales involved. However, they showed that, in Scotland, there is a desire to take more control of the provision of the pandemic stockpile and combine this with an overarching PPE and healthcare equipment policy which leverages the full buying power of the public sector.

556. Extending the role of the NSS may well have benefits in terms of strategy formulation, implementation and supply chain visibility at a Scotland-level as well as the development of a local supply chain. Its role in public sector procurement may also give it more buying power, although certainly not the same leverage as at a UK-level.

557. Whether a Scotland-led solution helps a UK-wide pandemic response is not at all clear. It may be useful as part of a Four Nation approach given that an enhanced NSS role may provide more visibility on PPE and healthcare equipment demand to UK government crisis planners than present levels of fragmentation.

558. However, if the decision were taken by the Scottish Government to deal with future pandemic needs on a unilateral basis, with no sharing of data or PPE and healthcare equipment between nations, there would necessarily be consequences in terms of UK supply chain resilience. Clearly an optimal UK-wide solution should be developed which fits both "business-as-usual" as well as pandemic needs for all Four Nations. Until that happens, DAs will feel that they need to pursue their own strategies to ensure that they address the weaknesses of the systems established before the Covid-19 pandemic. Whilst these new national systems may be an improvement on what went before, in my view, they will still be sub-optimal in terms of procurement and supply and not necessarily resilient enough to cope with future pandemics.

<u>Wales and Northern Ireland plans</u>

559. The Welsh Government (WG) has continued working with the UK government and other DAs on contingency planning for any new pandemic, whatever the source. As well as coordination with the other Four Nations, the WG says that it has developed cross-public

sector arrangements for planning, procuring and supplying PPE including a review of governance and decision-making.

560. Data sharing has also been highlighted as a major objective, providing visibility to local and national stocks through an inventory management system. This would include social care in addition to NHS needs and resources. The WG says it will continue to invest in the Stockwatch system, maintain the accuracy of data contained within the NHS Oracle Finance & Procurement System and maintain its PPE supply and demand model (WG, 2021a).

561. Use of local manufacturing resources has also been set as a strategic goal. However, the proportion of PPE and other healthcare equipment sourced by Shared Services and made in Wales is unclear.

562. The DoH and BSO PaLs in Northern Ireland have also adopted a plan which combines stockpiles, coordinated as part of the Four Nation approach, with the development of local supply chains and more effective procurement policies. In respect of the latter, it has developed a Dynamic Purchasing System (DPS) for PPE and other healthcare equipment which allows continuous tendering of contracts in line with stock levels and predicted need. It has also been suggested that the independent social care sector could be integrated into a central procurement process.

Increasing agility and supply chain resilience

Improving coordination across fragmented political structures

563. The provision of healthcare has been a devolved matter since the creation of the Scottish Parliament, the Welsh Senedd and the Northern Ireland Assembly in 1999. The Health Service in England remained the responsibility of Westminster. In terms of funding, the DAs receive block funding from the UK government using the Barnett formula.

564. Social care in England is the responsibility of local authorities, although the re-branding of the Department of Health to the Department of Health and Social Care shows a commitment to better integration between the two related services. In Scotland, Wales and Northern Ireland, social care funding and delivery are national responsibilities although delivery is also undertaken through local authorities.

565. NHS England led on PPE usage guidance policies, although as mentioned above, the frequency-of-use guidance was not always adopted by the devolved health services.

566. During the Covid-19 pandemic, whilst the UK government took the lead in coordinating purchases of PPE, the devolved health services also pursued their own procurement strategies. Scotland, for example, had three main sources of PPE: UK-wide procurement; its own orders from international suppliers and Scottish-based manufacturers. Although there were some concerns, there was no evidence that any country was prioritised for the supply of PPE throughout the pandemic (BBC, 2020).

567. The fragmented structure of health and social care (the latter also important in terms of PPE usage) across the UK makes formal and informal communication critical when assessing the UK-wide response to the pandemic and future resilience.

568. First Ministers were involved in COBRA meetings in March 2020, establishing a "Four Nation" approach to the response. In addition, Ministerial Implementation Groups (MIGs) were established involving ministers and civil servants from all the administrations. Meetings were convened daily (Anderson, 2021) but then replaced in June 2020 by two cabinet committees: Covid-19 Strategy and Covid-19 Operations to which DA ministers were not formally invited.

569. From 19 August 2020, Strategic PPE Four Nation (4N) meetings were held firstly on a monthly and from March 2021 on a quarterly basis, discussing, amongst other items, "mutual aid" and future supply (DHSC statement, INQ000528391, para 703).

570. "Mutual aid" across the four nations occurred on an ad hoc basis. Wales, for example, sent 13.8 million items to other UK nations between April 2020 and August 2021 and in return received 1.4 million items from Scotland and Northern Ireland. The UK government sent 3.3 million items to Wales. The DAs also loaned 20 million lateral flow test devices from allocated stocks to England in August 2021 (WG, 2021).

571. At one level, it could be concluded that relationships and structures established between the four nations were not a major issue of concern during the PPE crisis. There was no great variance in policies which would have led to a greater or lesser demand for PPE (although there was potential disagreement on technical guidance on the re-use of PPE) and no evidence that competing buying organisations artificially increased prices.

572. Whilst in theory the presence of additional buyers in the market could have an inflationary effect on the price of PPE and healthcare equipment, in the case of the DAs, the volumes of PPE which their procurement organisations were buying were so small in global terms that they are unlikely to have "moved the dial". In fact, DA health services were able to take advantage of contacts and market opportunities to act as additional channels to procure PPE and healthcare equipment which was then shared across the four nations.

573. However, there were tensions between the Scottish and UK governments over supply chain policy. It is clear that the Scottish Government wished to continue to procure its own PPE and healthcare equipment in opposition to a UK-wide approach proposed in April 2020 and that the Scottish Government should have access to existing supplies of face masks held in the UK PIPP stockpile in England on an appropriate four nation split (DHSC statement, INQ000528391, para 687). It was agreed on 9 April 2020 that, "The UK government would continue to buy at best efforts for the UK, but Devolved Governments were continuing direct procurement also" (ibid, para 694).

574. If an optimal model were to be adopted across the UK it would be essential for there to be:

- shared data on actual PPE usage;
- shared information on potential and actual supply chain risk and disruption eg delays in shipments due to geo-political security or supplier failure;
- a single model for projected usage ("burn rates");
- real time visibility of stock held at central warehouses across the four nations;

- more visibility of stock held by Trusts, boards and hospitals as well as primary and social care providers;
- a shared policy approach to the provision of PPE to both healthcare and social care settings;
- a database of suppliers and contracts awarded by all procurers of PPE (including Trusts, boards and other service providers) in order to enable the development of local buying consortia.

Author Recommendation 19

A structure should be established to enable formal communication between the UK government and DAs on PPE and healthcare equipment issues, meeting regularly in business-as-usual times to monitor the market and plan for emergencies. Although DAs will continue to manage their own procurement operations, data-sharing and shared decision making would be encouraged.

The benefits and disadvantages of greater centralisation

575. Across the UK, politicians have been prompted to look at greater centralisation of procurement to deliver benefits in terms of "business-as-usual" operations and preparedness for another public health emergency.

576. In the DAs, the majority of PPE and healthcare supplies are already procured and supplied by centralised organisations, although primary, social and private healthcare contractors largely make their own arrangements. As already discussed, Scotland has consulted on the development of the role of the NSS to include buying and supplying PPE for all health and social care providers, not just the NHS Boards.

577. In England, centralisation has been a key policy objective of the DHSC since before the pandemic and the following analysis of its success (and otherwise) could prove useful for the DAs' own plans.

578. A review of how non-specialist acute trusts in England could increase efficiency was undertaken by Lord Carter in 2015 (DHSC, 2016). The subsequent report had significant implications for the PPE and healthcare equipment procurement policies in place at the time of the Covid-19 pandemic. The structures it recommended still underpin the centralised procurement and distribution policies which exist today.

579. The Carter report concluded that it made sense to leverage NHS England's buying power to obtain highly competitive prices for PPE and healthcare equipment on the UK and global markets. NHS Supply Chain was subsequently established as the centralised procurement organisation to achieve this goal. However, after many years of existence, NHS SC has still to fully convince Trusts and other healthcare equipment buyers of the benefits of a central purchasing organisation.

580. The present arrangements for NHS procurement allow NHS Trusts either to use NHS SC as a central buying organisation, or purchase supplies themselves. This means that NHS

SC is both a supplier for the business of NHS Trusts (amongst others) and a competitor in the market.

581. With so many PPE and healthcare equipment buyers in the market, the landscape is complicated; influenced by frequent policy changes; duplicative and "siloed". The latter point relates to the multiple healthcare equipment budgets which exist preventing the development of scalable solutions both on the supply and demand-side. This provides a significant challenge in the implementation of a single supply chain resilience strategy.

582. In theory, more centralised purchasing would increase the effectiveness of the present NHS buying structures in England as well as making a future pandemic response more coordinated. The complexity of the procurement market in England was criticised in a report commissioned by NHS SC and the National Procurement Forum (NPF) by Unipart Consulting (a part of the logistics company supplying NHS SC). It observed that multiple and duplicative buying functions:

- diverted clinical time away from patients;
- increased excess stocks and waste;
- lacked process control regarding product safety including product availability, storage and replenishment;
- lacked the agility to support emerging ICS re-designs; and
- lacked professional development within the workforce.

583. It also asserted, "Driven in part by the need for resilience and reducing levels of storage capacity within hospitals, there is an increasing number of independent and isolated ICS [integrated care system] warehouses and investment plans emerging post-Covid, with no strategic connectivity to the national network in terms of storage, cost or capability. This can only lead to a duplication in cost and a division in supplier management. A lack of an integrated strategy on stock holding, location and management, drawing in local, regional and national assets and processes, will create a proliferation of small, disparate local warehouses, replicating cost and lacking control" (Unipart, 2022).

584. Overall, it highlighted that the existing and developing arrangements compromised the NHS SC's ability to increase value due to, "a lack of control and connectivity to local and emerging regional supply chain networks and processes".

585. The report also found that integrating local and national systems would be essential to future efficiency gains. "The lack of connectivity of local stock holding to the national supply channel compromises NHS SC's ability to hold resilient inventory".

586. One think tank, Our Scottish Future, has gone further asserting that it would be beneficial to extend centralisation of procurement to include healthcare providers in both England and Scotland. It claimed that £150 million could be saved each year if NHS Supply Chain's remit covered buying for Scottish health boards (Horne & Puttick, 2023).

587. However, in England, increased centralisation is impossible without wholesale changes to the status of Trusts which at present decide for themselves whether to use a central

procurement organisation or not. The fact that the NHS SC channel accounts for only a proportion of total NHS Trust's spend (57%) (Iacobucci, 2024), is an admission that there are weaknesses in the model. Trusts believe, inter alia, that:

- they can often buy a greater range of PPE and healthcare equipment more cheaply;
- they can buy locally and act with more agility to take advantage of market opportunities;
- the quality of goods they can procure themselves can be higher;
- they understand the needs of their HCWs better; and
- they can communicate their specific needs more clearly to the seller (Serle 2022a and Serle, 2022b).

588. As regards NHS SC's performance, in my opinion, the fact that more Trusts do not use NHS SC suggests that its customer service and value proposition is not overwhelmingly compelling.

589. In contrast, suppliers to local purchasing organisations can benefit from a more flexible approach to tendering which can favour smaller, local contractors with better customer service.

590. Regional collaborative procurement agreements, such as the Peninsula Purchasing and Supply Alliance (PPSA) covering south west England, bridge the divide between Trust-level and NHS SC. They are more accessible and flexible than NHS SC but also benefit from economies of scale.

591. NHS SC has plans to make its services more attractive but to do so requires investment, predominantly in technology and warehousing. For instance, it intends to bring online a new inventory management system (IMS) for use with 20 Trusts at a cost of £19.7m. It also wants to introduce a new warehousing management system (WMS) and e-commerce system as well as update its finance system.

592. Until NHS SC completes its transformation and more Trusts migrate fully (or more fully) to using its services, responsiveness to a future pandemic will be compromised through a patchwork of purchasing agreements and lack of visibility of inventory. To address the latter issue, NHS England has encouraged NHS SC to invest in a new IMS as well as making it responsible for rolling it out to Trusts which do not presently have one. This can only improve visibility and flows of data.

593. As NHS SC commented, "It [the roll out of IMS] will also allow NHS Supply Chain to leverage a system-wide view to reduce inventory costs, improve resilience, support clinical time being focused on clinical activities, and provide a safer patient experience." (NHSSC, 2023a)

594. However, larger Trusts which already use IMS will have to be persuaded to integrate these with NHS SC own systems if a system-wide view of inventory is to be achieved.

595. It should also be noted that local Integrated Care Systems (ICSs), bringing together the NHS, councils and voluntary sector, are being established in England to "develop shared plans and joined-up services" (NHS, 2022). It is unclear whether these partnerships will increase the complexity of the fragmented procurement sector, but there are no plans to extend the NHS SC IMS to them yet.

596. It must be noted that if in "business as usual" times, NHS SC was (and still is) unable to fully meet the needs of its biggest customers, then it is unsurprising that the DHSC needed to build a "parallel" supply chain during the pandemic.

597. An important question which should be asked is whether, in the event of another pandemic or major medical emergency, NHS SC should take the lead on the provision of PPE or whether this responsibility should be vested in an overarching authority, as in the pandemic.

598. If it is decided that NHS SC should take the lead, then there will need to be legislation changing the relationship between Trusts, the DHSC and NHS SC. The relationship would need to involve less "nudging" and more compulsion towards a centralised approach.

599. In return, NHS SC would have to improve service levels including order platforms, timeliness of delivery and customer service as well as improve on quality of products and price. This would be a big challenge given that it has struggled to convince healthcare equipment buyers that it can do this in "business as usual" times, let alone coping with surge capacity.

600. It is also important to see the issue from the perspective of the Trusts and other healthcare equipment buyers. They are trying to deliver value for money, quality products and efficiencies, which they believe the NHS Supply Chain cannot yet deliver on their behalf. They would undoubtedly not welcome coercion to adopt a supplier which could not fully fulfil their needs.

601. As one paper concludes (Boiko et al, 2020), "The COVID-19 emergency has shown that under conditions of system stress agile procurement is really important, which may not be well served by adherence to centralisation or by complicated supply chains. The narrative around NHS procurement should shift from reducing 'waste' to collaborating and empowering local managers to act in risk management mode during and post-crisis".

602. Consequently, unless many of the highlighted issues can be fixed by NHS SC in the near future, one option would be to leave procurement and supply chain decisions in the hands of the Trusts or ICSs. As long as there is centralised coordination and complete data visibility of inventory holdings, supplier capacities and usage rates, the high number of procurement organisations may be a benefit in terms of agility and flexibility.

603. Such a structure would be sub-optimal in the eyes of many central planners and policy makers, due to the inconsistency of prices and types of products being ordered and a lack of control of the overall system. However, as long as there is an over-arching organisation which has access to complete PPE and healthcare equipment supply chain visibility, this may still deliver a resilient supply chain.

Author Recommendation 20

There should be a single authority responsible for ensuring the resilience of the UK's PPE and healthcare equipment supply chains. Its remit should include visibility of all inventories held in the UK including those of NHS Supply Chain; the DA's centralised procurement organisations; Health Trusts; Primary and Social Care providers; government departments as well as private sector manufacturers, wholesalers and distributors. The authority would act as a "Control Tower", identifying risks; monitoring orders; tracking shipments and assessing inventory levels. The authority would also be responsible for developing a single model to forecast demand and usage rates of PPE which would inform more accurate order policy.

A decision should be made by government on the role of NHS Supply Chain in the provision of PPE and healthcare equipment in England. Its present status as supplier as well as competitor to the Trusts is ambiguous and leads to confusion, exacerbated in times of stress. It must either take over as a single central procurement organisation, which will require major governmental legislative efforts, or Trusts should be allowed to procure in the way they see best suited for their operations, focused around Integrated Care Systems (ICSs), doing away with the need for NHS SC. If the former is decided, NHS Supply Chain requires significant investment and must improve its service considerably. If the latter, the Trusts (or ICSs) must be held accountable for ensuring the resilience of PPE and healthcare equipment supply chains in the event of another pandemic.

Mitigating the impact of government policy and technical advice on supply chains

604. During a pandemic, changes to technical advice and guidance on the use of PPE are inevitable as the understanding of the characteristics of a disease evolves. It is likely that advice at the outset of a potential medical emergency will err on the side of caution. As understanding of a disease evolves, advice will become more evidence-based and this may result in guidance being relaxed.

605. However, it is important that medical experts have an understanding of the impact of their guidance on supplies of PPE and other healthcare equipment. These consequences must be clearly communicated to them by relevant supply chain experts before advice is adopted and looked at "in the round". It would be highly detrimental for medical care and the safety of HCWs if overly cautious advice led to the shortage of essential PPE through unnecessary usage policy.

606. It is also critical that the PPE supply chain is robust and resilient enough to cope with the surge in demand that a new pandemic would create. In terms of planning, input from medical experts must inform likely levels of PPE required, not just for influenza or Covid-19, but for all diseases. Exercises testing out the UK's preparedness should factor in frequency of use guidelines to provide risk managers with estimates of volumes and type of PPE required at:

- the outset of a pandemic;
- as the pandemic evolves; and
- as the pandemic ends.

Author recommendation 21

There should be high level liaison channels between those setting the usage guidelines and those in charge of the PPE/healthcare equipment response. Although it is understood that technical guidance on the use of PPE will evolve throughout the course of a pandemic, those experts responsible for the changes must be mindful of the impact of their advice on supply chains and must consult with supply chain experts prior to new announcements.

The potential for diversification of supply

607. As this report has already laid out, there are significant risks to supply chains emanating from an over-reliance on single/sole suppliers or single markets. An industry wide trend has led manufacturers, retailers and other procuring organisations to implement supply chain strategies to mitigate risk by:

- reducing reliance on China as a manufacturing source ("China Plus");
- supporting and/or establishing local manufacturing; and
- building up stockpiles of PPE at strategic locations

608. All of these policy goals have their strengths and weaknesses. Firstly, there are very good reasons why China has developed as a hub for the production of PPE, not least due to its cheap labour, extensive manufacturing capabilities and strong transportation links with the rest of the world. Its dominance is such that these factors will be difficult to replicate elsewhere. Moving to a "China Plus" solution is a reasonable goal, but it will take time for other developing countries to develop PPE production although this may well eventually be an opportunity for other markets in Asia and Latin America. However, if there is another pandemic, many of the reasons why the global PPE market became dysfunctional will remain: disruption to transport; inability to scale up production; potential quality issues; export bans and governments diverting production to domestic markets.

609. The second policy goal would be to develop domestic manufacturing capacity. However, encouraging manufacturers in Western countries to invest in the production of low value PPE would be difficult without significant support. European and North American manufacturers which have stepped up to re-purpose their production lines to the making of PPE would only do so in the short term. Their business models nowadays are predicated on building high quality, high value goods to repay significant levels of capital investment.

610. Consequently, a new generation of manufacturers will be required, although this will be challenging in business-as-usual times when they would normally be uncompetitive against Chinese competition. The economics would not work using traditional manufacturing methods without significant state protection and subsidy. Appetite for such support – seeing as it would potentially financially harm healthcare organisations through higher tariffs as well as divert money away from frontline services – would be difficult to sustain after a few years, especially once memories of Covid-19 fade. However, there is an alternative. Some Western manufacturers have been successful in the market by

investing in automation which reduces the labour component of costs. As already recommended, this should be a key policy goal for the UK government.

611. Whilst it may be possible to invest in and support UK domestic manufacturing, it is more problematic to secure entire supply chains. This includes upstream raw materials, intermediate goods and components. In crises many of these goods may be subject to export bans or restrictions by foreign governments. For instance, complex meltblown fabrics used in the production of gowns are largely produced in China and having the capability to cut and sew garments in the UK would not address the supply chain chokepoint (Cabinet Office statement, INQ000497031, para 14.2)

612. Thirdly, there is the option of stockpiling. Given the nature of PPE this is a very feasible option although items do have expiry dates and re-testing would need to take place when necessary. In conjunction with industry, it would certainly be sensible for the government to take a science-led approach to explore the feasibility of extending these shelf-lives. As the economics think tank, Bruegel, put it, "Precautionary stockpiling of non-perishable medical goods and provision of intensive-care beds and medical testing facilities do not need local production, and would have gone a long way to alleviate the shortages currently experienced" (Poitiers and Brekelmans, 2020).

613. Although this may seem a sensible option, in practice to store the volumes of PPE required to cope with another health emergency on the scale of Covid-19 would not be straightforward as well as being costly. Given that it is impossible to know how long it will be until the next pandemic, the expense of long term storage and maintenance will become increasingly politically difficult to justify when balanced against other healthcare budgets. Even after the pandemic, between January 2022 and January 2023, the government spent £312m on storing PPE (Aurora, 2023) although, prior to the pandemic, logistics company Movianto was paid £55 million for a five year contract to store and manage PIPP stockpiles. Even in post-Covid "business as usual" times, however, the UK government and DAs have committed to increase stockpiles from 2-4 weeks to up to 15 weeks which will necessarily have a major impact on future costs. These stocks will need maintaining to ensure that PPE remains in-date and appropriate to potential needs, although a smarter solution to managing PPE inventory is outlined below.

Author recommendation 22

The UK and (where feasible and appropriate) DA governments should adopt an approach to stockpiles which combines elements of three potential options. Firstly, strategic stockpiles should be built up to cover emergencies. Secondly, longer term relationships with Chinese and, critically, non-Chinese suppliers must be maintained or developed, even taking into account the possibility that these channels may be rendered ineffectual in a pandemic. Thirdly, some contingency for national production should be put in place. It may be feasible for governments to retain manufacturers to provide PPE and healthcare equipment production capacity which can be switched on at short notice. In the longer term, given the potential for automation and 3D printing in the future, Quick Response manufacturing may become more attractive in this sector as low cost labour becomes less a factor in the production of PPE.

Ensuring appropriate levels of PPE and healthcare equipment stockpiles

614. The major issues related to ensuring appropriate levels of stockpiles of PPE include:

- Demand. What type and volume of PPE will be needed for the next pandemic? There is no guarantee that the next pandemic will resemble Covid-19 and, consequently, the types and volume of PPE may differ according to the nature of the pathogen and relevant medical advice.

- Supply. What are the risk factors in a strategy which involves replenishment of PPE stockpiles from abroad? It is clear that if a future health emergency originates in China, its government may restrict the export of PPE as it did during the Covid-19 pandemic. Diversifying sourcing to other countries in Asia may not be the best option as the same pressures are likely to be applied as any disease spreads throughout the region. Risk mitigation would involve a mix of far-sourcing, near-sourcing (from suppliers based in Europe or North Africa, for instance) and domestic supply. The latter is the most resilient in terms of political and international transportation risk, but most costly even if domestic production exists (which it may not). Whilst such a tiered approach to sourcing is being actively pursued in markets such as the USA (where there is a large manufacturing sector in existence), the UK is more restricted in its options.

- Storage. Many items of PPE have expiry dates which means that they either have to go through a process of re-testing or need disposal. Some healthcare equipment such as ventilators require maintenance during their storage in order to ensure they work when deployed in a crisis. This is likely to be very costly. Whilst in the light of the Covid-19 pandemic it would seem to be sensible to increase the size of PPE and healthcare equipment inventories, this is unlikely to be a viable long term solution, as discussed above. Depleted stocks may not be replenished due to a reduction or redeployment of budgets, especially after many years without a pandemic. It would be sensible for government to undertake and publish detailed costings associated with different options to increase the supply chain robustness.

615. Many of the measures which can be taken to make supply chains more resilient cost more than the status quo and the decision to incur such expenditure will become harder to justify the more time elapses from the last pandemic. To prevent budgetary issues being prioritised over resilience by procurement organisations, any solution needs to be integrated into existing supply chain operations and should reflect best practice. Thus, the benefits will be experienced in the day-to-day running of the operations of healthcare providers and not seen purely as a cost driver absorbed by general healthcare budgets.

<u>Smart solutions for the planning and management of stockpiles</u>

616. There are "smarter" solutions than solely increasing the amount of emergency or buffer stocks with the attendant issues of cost and redundancy. These include so-called "rotating" and "virtual rotating" stockpiles. These inventory management approaches are of equal relevance both to high value, complex products such as ventilators as well as cheap, high volume products such as PPE.

617. "Rotating" stock involves introducing warehoused product into the supply chain when it is approaching its use-by date. In simple terms, this prevents the risk of stock expiring, in effect using products held in the emergency stockpile to fulfil normal customer orders (for example, those placed by healthcare providers) and replenishing with new stock. This technique was known to SCCL although it was only used for gloves at the PIPP warehouse managed by Movianto (SCCL statement, INQ000492085, para 17.31). It avoids the costs of waste, disposal and handling and enables products to act during their lifetime as both emergency stock and supply chain inventory although it requires a level of integration between emergency stockpiles and business-as-usual inventory holdings.

618. In the "virtual rotating" stockpile model, the customer (in this case the government) would place contracts with multiple suppliers requiring them to keep an excess of PPE and healthcare equipment in their own inventories (rather than stored at a government central warehouse, hence the term "virtual") above and beyond usual stock levels. Instead of being untouched and separate from the rest of the supplier's stock, the inventory would be used to fulfil normal commercial needs and production levels or sourcing decisions would be flexed to replenish stock. Hence, the inventory would always remain at the appropriate level (whatever this was set at) and there would be no on-going maintenance costs to ensure that old stock was still usable.

619. In the case of ventilators, a traditional approach to emergency stockpiling would involve the government assuming large up front capital costs, costs of depreciation, as well as maintenance and storage costs. Over a period of time, this could amount to more than the initial value of the products.

620. Using the "virtual rotating" model, in the event of a pandemic, ventilators could be distributed from a manufacturer's stockpile which, in order to prevent disruption to supplies from potential export bans, would need to be based in the UK. A further advantage would be that, as technologies improve, the model would ensure that ventilators would be upgraded over a period of time, unlike in the traditional emergency stockpile model.

621. The same model would work for PPE. An online inventory of items would be held at a central database, but physical stocks of masks, goggles, gowns etc could be held at multiple distributors' or manufacturers' facilities. Specific benefits from this model for PPE include:

    - the model overcomes the problem related to the expiry of products at the end of their shelf life. Orders are often placed in bulk which can mean a large proportion of stocks becoming out-of-date all at the same time. Instead, suppliers would store, manage and rotate stock according to expiry dates;

    - the government would still own stock and it could be distributed at a time of crisis. The difference from the traditional model would be that distribution would not be from a centralised stock location but from various suppliers' facilities;

    - the government would also benefit from managing procurement costs over a longer period of time rather than making bulk purchases; and

- there would be fewer risks from fire, flooding etc than at a centralised stock location.

622. Suppliers would be remunerated through a fee for inventory management.

623. Whether "rotating" or "virtual rotating", the challenge would still be to set inventory levels appropriately, although data from the Covid-19 pandemic will help to inform such decisions. There would remain the need for the distributor or manufacturer to replenish the inventory after the first phase of any pandemic. In this respect, "virtual" stockpiles face the same challenges as physical. The overriding benefit is that they would be a more cost-efficient way of maintaining appropriate levels of stock and ensuring that levels of redundancy are kept low. Also, manufacturers would benefit from more predictable and less "lumpy" orders as inventory was drawn down to fulfil commercial orders and stock replenished in an orderly way. This is in contrast to large orders for PPE to replenish previous orders which may have gone past their use-by dates. In the USA, PPE manufacturer 3M has been lobbying the government to adopt such an approach (3M, 2020).

624. If the "virtual" stockpile is held with a manufacturer, rather than a distributor, the capability of scaling up production will be essential to replenish stocks in the event of a pandemic. This could be a key disadvantage of the model compared with a physical stockpile as it relies on the ability, reliability and willingness of the supplier to meet commitments. This would be an important aspect of any contract/tender process and would involve an approach in which cost was moderated by other factors, such as levels of trust.

625. A key challenge of holding inventory on a decentralised basis at multiple, dispersed locations is visibility. However, the flexibility provided by new software applications increasingly gives companies the option to fulfil orders from a single "virtual warehouse", whilst their physical inventory is spread out over several facilities. Operations like this, once impossible, are now becoming more widespread and will result in the more efficient use of space and inventory.

Author recommendation 23

Emergency stockpiles should be held on a virtual and rotating basis by distributors and manufacturers augmenting and even replacing government-owned centralised distribution facilities. This will remove the risk of out-of-date or unmaintained equipment (especially ventilators) and reduce the cost to the government.

Building resilience through local supply chains

626. Market realities will also influence attempts to develop a UK domestic PPE and healthcare equipment sector. In theory, a significant and scalable manufacturing base would enable the UK to quickly respond to spikes in demand caused by a pandemic or other medical emergency. Such a "Quick Response" strategy would allow stockpiles to be quickly topped up rather than relying on manufacturers based in other countries where reliability of supply could be in question.

627. This aspiration is shared by the UK government and the DAs over and beyond the UK Make programme already discussed. In conjunction with its aim to centralise procurement of PPE and healthcare equipment for all public bodies, the SG has asserted that, "The intention is to retain as much domestic manufacturing capacity as possible" (SG, 2022). In Wales, the WG has stated that it would, "build on the work already undertaken by CERET to review the respective merits of local production against international purchases" (WG, 2021a). The Northern Ireland Audit Office commented that, "Local manufacturers have…contributed significantly towards strengthening local supply chains, and their continued involvement will be key to ensuring stronger and more sustainable supply confidence" (NIAO, 2022).

628. The challenge lies in creating an economic environment in which it pays for UK manufacturers (or international companies with factories in the UK) to establish and maintain production lines, particularly in the face of a surfeit of PPE and low prices on the global market. As already mentioned, labour costs are a strong disincentive to production in the UK and unless new technologies and automation can "level the playing field" it is likely that manufacturing may only be sustainable with some form of government support.

629. The situation has been illustrated by a communication to buyers of PPE by NHS England, in this case related to facemasks. In advice entitled, "FFP3 resilience principles in acute settings", it informed Trusts that, "Frontline stocks will be managed at no more than 7-10 days per SKU [stock keeping unit]. This ensures that stock rooms have enough space to hold a wide range of FFP3 and more UK Make is available. High local stockpiles of FFP3 that have been stored due to previous ordering/delivery arrangements should be considered for redistribution" (NHS England, 2023).

630. It seems that NHS England is trying to encourage hospitals to diversify their range of PPE in order to encourage sales of UK Make products. In my opinion, the large stocks of PPE which were left over from the pandemic are reducing the ability of UK producers to develop sustainable business models.

631. This is further reinforced by the mandate in the advice note that, "UK Make masks will be used for all new Fit Tests (high supply resiliency and excellent fit test performance) when appropriate for the individual." In other words, HCWs will eventually migrate to using UK manufactured face masks over a period of time. It would be useful to know how effective this strategy is proving in light of the huge stocks of PPE which "overhang" the market.

632. In reality, the UK and devolved governments have a limited number of options in terms of creating a UK domestic PPE manufacturing base. In addition to encouraging healthcare providers to buy locally, for example, by placing UK manufactures on to lists of "framework" suppliers, they could support businesses by helping with the cost of investment in capital equipment (as has been the policy in Australia) beyond existing tax breaks.

633. Further steps would be to subsidise UK-based manufacturers by, perhaps, buying at an above market price. However, this would raise questions about:

- the legality of supporting one company over another;
- whether this would be a valid use of taxpayers' money; and

- whether it would be a valid use of health budgets.

634. As previously mentioned, policymakers' views on spending money in such a fashion may change in the coming years as the memories of the crisis fade.

635. A further option would be to nationalise parts of the PPE and healthcare equipment market as part of a more interventionist industrial policy. Without rehearsing all the arguments for and against public ownership of manufacturing companies, there would be:

- significant costs involved for the taxpayer;
- there is no guarantee that the state-owned manufacturer would have access to the capital it may require for future investment; and
- customer service could be compromised.

636. A public manufacturer in the sector would also potentially distort the market, especially if subsidised. Unless compelled, PPE and healthcare equipment procurers might still buy products on the global market if they were cheaper and of better quality. Should the government subsequently attempt to protect state owned companies by the use of tariffs, the additional cost burden would be borne by healthcare providers (and ultimately taxpayers).

637. Governments may have more success by strengthening business eco-systems of existing manufacturing sectors, that is, by encouraging and supporting the growth of sectors such as textiles, plastics and electronics. Developing a more substantial and diverse manufacturing base which could respond to the increasing need for JIT/Quick Response production in the UK would also create more opportunity for businesses to switch production capacity to PPE and healthcare equipment should there be another pandemic. For comparison, textile manufacturers in Turkey and Bangladesh were able to quickly re-purpose clothing production lines to make face masks and gowns during the crisis.

638. As was found during the pandemic (especially as regards ventilators), it is far easier to scale up existing production capabilities rather than start from scratch. The critical period of PPE and healthcare equipment shortages is likely to last a relatively short time (perhaps two months as was the case in Covid-19) before global supply is able to respond. Therefore, the ability to increase domestic production needs to occur within days to cover the period between the time national stockpiles run out and products can be sourced reliably again on the global market.

Author recommendation 24

The UK and (where feasible and appropriate) DA governments should enter into agreements with domestic manufacturers which would ensure that they could scale up production to cover the period after national stockpiles are depleted but before the global market recovers capacity. Investment in automation will become an important policy goal for the UK government as well as a strategic ambition for UK manufacturing.

Developing diversity in supplier base

639. As mentioned above, the UK government and DAs are cognisant of the need to create an on-shored production capability. The Covid-19 pandemic showed that even long term, reliable trading partners would, under extreme domestic political pressure, put in place export bans on PPE.

640. This is particularly relevant to the UK when examining the efficacy of a near-shoring, multi-shoring or friend-sourcing strategy. Whilst these policies may mitigate risk in normal times and reduce dependence on suppliers based in potentially adversarial markets, when, in a pandemic, even neighbouring countries are restricting the flow of essential products such as PPE, another approach is required. In my view, near-shoring is not enough on its own to ensure supply as governments of any foreign country could not be relied on to maintain contractual agreements which may exist.

641. Indeed, given the way in which the pandemic spread around the world, it may be that a sourcing strategy which involves multiple, regionally diverse, far-sourced suppliers is more resilient. Whilst, for example, there would be disruption to supply of PPE from Asia by an Asian-originating disease at the beginning of the pandemic, this disruption would then pass to other regions depending on the progression of the disease. Ensuring contracts were in place with other suppliers in a variety of different locations (such as in Africa or Latin America) would help the UK through the period after stockpiles ran out and supplies from Asia normalised.

642. Near-shoring of production to non-EU countries, such as those in North Africa, may form part of this diversification policy. However, shipments may have to be moved by air or by short sea shipping rather than by road through Europe if EU export bans are in place or requisition policies pursued.

Author recommendation 25

Suppliers of PPE and healthcare equipment should be located strategically in different parts of the world, to account for the geographic spread of the disease and the impact that this might have on the ability to produce and supply goods (e.g. due to lockdowns or export bans).

The use of technology to improve visibility of supply chains

643. The introduction of advanced Supply Chain Management software will be critical to better visibility of PPE and healthcare equipment supply chains. Systems are designed to relate demand forecasts for products with the co-ordination of supply; schedule manufacturing and provide the relevant data for metrics for performance analysis. This ensures the optimisation of inventory and the relation of marketing and sales effort to production and logistics in a close collaborative effort.

644. Supply Chain Management (SCM) software can be broadly divided between those applications which focus on Supply Chain Planning (SCP) and those which focus on Supply Chain Execution (SCE).

645. Supply Chain Planning software would be used to determine requirements for warehousing, distribution channels and inventory holding locations over a 2-3 year (or more) period. Typical tasks undertaken by SCP software include:

- network planning and design;
- capacity planning;
- scenario planning and real time demand; and
- manufacturing planning.

646. Whereas SCP systems are designed to give managers a long term time horizon (months and years in advance) and operate at a strategic level, SCE systems are much more operational, allowing supply chain tasks (such as in the transportation or warehousing functions) to be completed effectively in minutes. SCE software typically includes:

- Transport Management Systems (TMS);
- Warehouse Management Systems (WMS);
- Inventory Management Systems (IMS); and
- Order Processing.

647. Of these, NHS SC has been investing in WMS, IMS and order processing systems, the latter being the e-Portal and other platforms deployed during and after the pandemic.

648. Systems will also be provided by the third party logistics and transport companies used by NHS Supply Chain, including TMS. These systems should integrate as part of the Supply Chain Management architecture, providing real time, end-to-end updates to the customers (eg the Trusts) as well as NHS Supply Chain.

649. Whilst SCM technology has been around for many decades, one of the latest iterations, Automated Inventory Management (AIM), utilises Artificial Intelligence (AI) software to track, manage, and optimise stock levels without significant human intervention. It automates various tasks traditionally handled by manual processes, resulting in increased efficiency, accuracy, and cost-effectiveness. IoT sensors generate data related to quantity, status and performance of products and this is fed into the AI system which can then be used to make decisions such as when to re-order products and in which quantities.

650. Benefits of Automated Inventory Management include:

- reduced costs;
- improved customer satisfaction;
- better decision-making; and
- increased scalability.

651. As with all systems, the results are heavily dependent on the quality of data being inputted. Inaccurate, incomplete or out-of-date data will produce inaccurate forecasts and result in sub-optimal decisions being made. Data privacy is also an issue which has to be addressed through measures such as encryption and anonymisation. The implementation of an AIM can also be complex due to the infancy of the technology and the complexity of the data involved, although this situation is likely to change rapidly in the future (Dovhal, 2024).

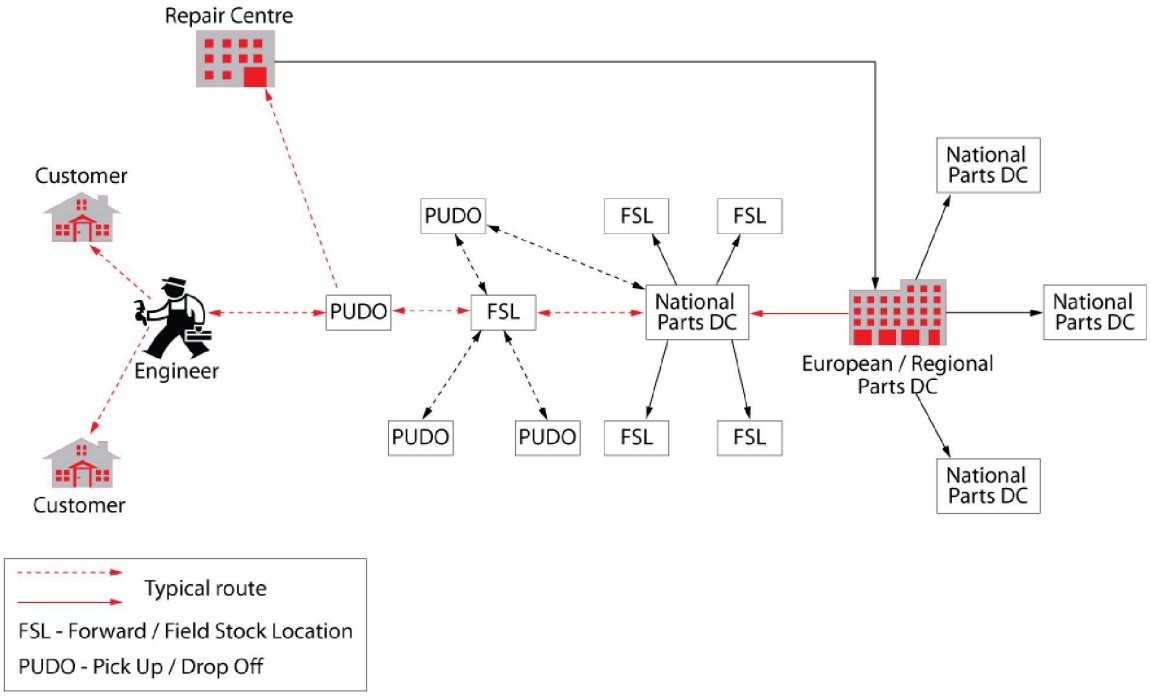
The use of technology to monitor supply chain effectiveness

652. The complex and distributed nature of inventory holdings at multiple levels throughout the UK's fragmented healthcare system is unique, especially given the complicated relationship which exists between Trusts (and other buyers), NHS SC, distributors and manufacturers and the DHSC in England and the alternative arrangements made in the DAs. This inhibited the effectiveness of the UK government's response as visibility of dispersed inventory levels even within England's healthcare system was poor. As SCCL commented, "The absence of a centralised inventory management system [for Health Trusts] clearly gives rise to serious issues during the pandemic…" (SCCL statement, INQ000492085, para 7.44).

653. However, a parallel can be drawn with the service/spare parts logistics market in sectors such as electronics, automotive or utilities (gas, telecoms etc). Complex relationships exist between manufacturers, wholesalers, distributors, engineering companies, garages etc and, as a consequence, multiple distribution channels have developed with inventory being held locally (at locations in close proximity to customers in order to meet high service levels/delivery schedules), regionally, nationally and in some cases globally. The number of supply chain parties involved means that there is a high risk that inventory holdings can proliferate. The only way to prevent this is through strong inventory management facilitated by visibility systems. There are some major differences – in comparison with PPE, there are many more types of spare parts meaning higher levels of supply chain complexity. However, there are still benefits to be gained from the comparison.

654. Figure 30 illustrates the complexity and hierarchy of a spare parts distribution network involving regional, national and local inventory holdings. The equivalent comparison between "field stock locations" in the healthcare sector would be primary care organisations such as surgeries, demonstrating that it would be possible (technologically at any rate) to keep track of inventory holdings even in a highly fragmented environment.

Figure 30. Organisation of a spare parts distribution network



Source: (Author, 2019)

655. An effective Service Parts Logistics strategy relies on creating end-to-end supply chain visibility enabling decisions to be made to match supply and demand, taking into account disruptive events. The Control Tower approach (already outlined earlier in the paper) allows a supply chain manager to identify:

- delayed orders;
- discrepancies and variances;
- quality issues;
- SKUs at risk from shortage (based on days of coverage); and
- inventory levels, planned deliveries and modelled consumption.

Figure 31. Inventory Management System example showing SKUs at risk

Source: (Deloitte, 2020)

656. Figure 31 shows the level of detail that is now available to a supply chain manager in the healthcare technology equipment sector. The screenshot reveals how disruption in the supply chain may impact orders and the effect this would have on inventory at a product level including the days of coverage left. For example, “humidifiers” have only 3 days of inventory coverage and 20 orders have been impacted by a disruption, whatever this may be. This alert will allow the manager to take remedial action, if deemed necessary, to prevent stock outs.

657. One difference worth noting is that whilst the UK government is responsible for the PPE response in a pandemic and so has an interest in ensuring the efficiency of the overall

supply chain, it only has limited powers to implement solutions which would optimise its response. Multiple silos and lack of visibility compromise this efficiency and effectiveness.

Case Study - Catena-X

An industry with a similar challenge is the automotive sector. Disruption to supply from events such as the war in Ukraine and the re-routing of ships around the Cape of Good Hope, has led BMW to establish a data cooperation platform with other major German automotive companies and parts suppliers (DLR, 2024). Called Catena-X, the neutral platform is designed to facilitate multilateral flows of data, rather than the bilateral flows which existed before. Individual data flows can be linked and standardised, a concept which if applied to the PPE and healthcare equipment supply in the UK, could provide visibility on demand, supply and inventory holding of the multiple parties involved. The €100m development of the platform was funded by the German government. It has created a data exchange for all companies involved in the automotive supply chain from SMEs to multinationals. According to the Fraunhofer Institute (2024), one of the partners, it provides:

- traceability: generation of a data chain for seamless material tracing for compliance with the European Supply Chain Act;
- demand and capacity management: cross-tier solution to optimise demand and capacity for proactive risk management; and
- sustainability: continuous transparency of product carbon footprint including the installed components across all tier stages.

658. The technology exists to provide high levels of inventory visibility to a highly granular level i.e. even to stores held on hospital wards, in surgeries or care homes. In addition, the present generation of technology is capable of providing visibility across multiple organisations, end-to-end supply chain modelling and forecasting functionality.

659. What is more challenging will be encouraging or compelling the full range of supply chain players to adopt these tools within a highly fragmented PPE “community”. As has already been noted, NHS Supply Chain only accounts for a proportion of PPE sales to NHS Trusts and other organisations in England. An overall UK preparedness strategy would require visibility of all PPE supply and demand, not only in specific health and social care sectors but also across the Four Nations. This is in addition to other critical agencies which have PPE and healthcare equipment needs, such as the Ministry of Defence.

660. In England, the view of SCCL is clear. “There is a recognition that this problem will be alleviated were every Trust to have an inventory management system which would give greater visibility of stock held in particular hospitals. At the moment only a relatively small number of NHS Trusts have such a system” (SCCL statement, INQ000492085, para 7.44). However, it also admits that funding for such an initiative is limited.

661. In addition, visibility needs to be extended up and down the supply chain. Downstream, it would be useful to find out how many health and social care providers use Inventory Management Systems and how easily they could be integrated on a national basis. Upstream, how much visibility of suppliers’ supply chains exists? Ultimately, what is

required to implement a central control tower solution which takes a holistic view of the UK's PPE needs and supplies?

Author recommendation 26

An ambitious project should be implemented to map inventory holdings upstream and downstream across the UK. As well as centralised procurement organisations, health and social care providers, this will include manufacturers and distributors. Once this has been undertaken, an Inventory Management System, either new or existing, should be initiated which will allow real time tracking and decision-making through the use of new technologies such as AI. Government should use its influence to ensure that all supply chain parties engage with this initiative.

The role of organisational structures, systems and processes to effective supply chain resilience

662. It is useful to look at the organisational structure of other large organisations when identifying best practice in implementing supply chain resilience strategies. Retailer GAP is one such business which is regarded as operating a "gold standard" response to disruptive events.

663. The retailer assesses risk at an enterprise, brand and asset (warehouse, call centre, server centre or retail outlet) level. The company has developed a framework to manage risk including social, regulatory impact and climate change. On each of the major risk factors it maps its own preparedness against the potential size of the impact. The risks are measured on the basis of financial, material and reputational impact.

664. At the enterprise level, risk is monitored on an ongoing and annual basis and any change is reported to the Board. At an asset level, GAP deploys Business Continuity Planning (BCP) teams, which, amongst other issues, address the potential impact of extreme weather events.

665. Each year GAP undertakes an annual risk assessment which involves interviewing 70 senior managers. Based on the findings, the Internal Audit team summarizes the most important risks to the enterprise. GAP's Social and Environmental Responsibility team, with direct links to CEO and its Executive VP of Supply Chain, works with the Environmental Council which meets quarterly to identify and prioritize risks.

666. It is the role of the BCP to produce company-wide programmes which address preparedness, emergency response, crisis management and business recovery. This will include plans and documentation, as well as training, which will allow for the better protection of the business, its reputation, assets and employees.

Figure 32. GAP's Business Continuity Plan (BCP) organisational structure

Source: (Author)

667. Electronics manufacturer Cisco is another company which has very robust organisational structures in place to deal with disruption. In 2011, Cisco's crisis response plan was put to the test as a result of an earthquake and tsunami in Japan. Utilising business continuity data and processes, all direct suppliers, their associated sites and components and other critical supply chain nodes in the impacted area were identified within 12 hours of the initial earthquake. In the first few days following the incident, Cisco's incident management team was able to:

- establish contact with suppliers to assess the impact of the incident on site capacity;
- develop a prognosis of their ability to continue to produce; and
- identify their ability to distribute components.

668. Cisco managers were also able to profile each supplier site from various resiliency perspectives. These included:

- the expected time-to-recover (TTR) for the site;
- back-up power generation capabilities; and
- whether the supplier's components were single sourced or had alternative sites available.

669. Cisco's supply chain incident management team war room approach, structure and operations were based on their supply chain risk management (SCRM) incident management "playbooks". The playbooks define a functional track structure, key contacts related to various types of incidents, templates and other collateral to assist in running and managing an incident response. The response team had direct links to the Chief Executive Officer who received regular briefings and was involved in major decisions, personally signing off on budgetary issues.

670. The best practice demonstrated by these two companies has common themes:

- they have teams continuously monitoring the market for economic, political, societal, security, environmental, legislative and technological disruptive events;
- they rely heavily on insight and intelligence at an "asset" level for potential risks;
- they have structures in place which act as a conduit of information and data to higher decision-making functions, bottom up. These structures also channel information and decisions from senior management to operational functions;
- they have established "playbooks" – standard operating procedures – in the event of disruption;
- the technology they use provides visibility of their suppliers (below multiple tiers) and enables assessment of risk from disruption;
- technology also provides real time alerts for potential disruption to international shipments;
- on a medium-long term basis, management ensures that resilience is "hard-wired" into their supply chain strategies by identifying areas of vulnerability (such as single-sourcing) and taking steps to mitigate; and
- there are established channels for escalating concerns over potential risk events so that senior management is informed and can make decisions swiftly when required.

671. It is very important to note the critical nature of the availability of data and its flow throughout an organisation. Specific to the UK's supply of PPE and healthcare equipment, visibility of the following stocks would be essential:

- emergency (PIPP) stockpiles in England, Scotland and Wales;
- NHS Supply Chain warehouses in England;
- inventory held in warehouses managed by NSS National Procurement in Scotland, NHS Shared Services System in Wales and Procurement and Logistics Service in Northern Ireland;
- inventory held by Trusts and Primary Care Organisations;
- PPE stocks held by Local Authorities for Social Care; and
- stocks held by MOD and other relevant government departments.

672. Significant stocks of PPE and healthcare equipment are also held in the private sector as part of the normal operations of distributors and manufacturers. More collaborative partnerships and data sharing with both types of supplier would allow greater visibility of their inventory holdings. Direct relationships with manufacturers, both in the UK and overseas, which leveraged not only the NHS's buying power but also its supply chain influence, would give the procurer's central risk function more power to implement visibility projects.

673. One major difference with the two case studies highlighted above is the level of control and power which these two companies are able to exert not only over their supply chains but within their own organisation. Whilst the UK government has assumed overall responsibility to ensure that there are appropriate levels of PPE, it does not control all the procurement channels or, consequently, the supply chains. However, steps could be taken to improve visibility of those channels which it has some leverage over (NHS Supply Chain, PIPP stockpiles, Trusts, government departments and local authorities) leaving aside the DAs, distributors and manufacturers.

Author recommendation 27

A step towards increasing visibility and supply chain influence would be to create a position and department which would be responsible for not only the "business as usual" provision of PPE and healthcare equipment to the UK market, but in the event of a healthcare emergency or pandemic, would be able to activate a response playbook involving a pre-agreed set of standard operating procedures. It would also be responsible for ensuring the proper utilisation and subsequent replenishing of inventories whether these are PIPP, NHS SC or Trusts, Health Boards etc. Clearly this would be a major task for the UK government to implement alongside DA counterparts.

What lessons can be learned from international practices and experience of the pandemic?

674. The possibility of a major pandemic had been discussed and planned for since at least the H5N1 avian influenza in Asia in 2003. The World Health Organisation consequently issued guidelines for developing national pandemic plans and these have been widely adopted.

675. Despite this, the individual arrangements for the provision of PPE varied substantially at the outset of the pandemic on a country-by-country basis.

676. Italy was the first country in Europe to be hit by the pandemic. Law Decree 81/2008 made the provision of PPE the responsibility of health organisation employers, working in conjunction with The Department of Civil Protection and the Local Health Authorities (LHAs). The National Plan for Preparedness and Response to an Influenza Pandemic also makes the supply of PPE a regional responsibility (nineteen regions and two autonomous provinces) and this proved to be the basis of the country's Covid-19 response.

677. However, the non-centralised approach attracted criticism by the then Prime Minister of Italy, Giuseppe Conte, who commented, "[the regions are] in charge of implementing healthcare but not prepared to face a national emergency" (Bosa et al, 2021). Like all

other countries, there was an acute lack of PPE at all parts of the healthcare network, not least in care homes. Consequently, a more centralised approach was taken and a commissioner in charge of coordinating centralised procurement was appointed. The Civil Defence Department was put in charge of procurement and distribution of supplies to the regions. At the same time as this, hospitals and regional authorities continued to source PPE themselves.

678. In France, a 2013 directive by the General Secretariat of Defense and National Security (SGDNS) established that the provision of PPE for HCWs was the responsibility of employers. In effect, this meant hospitals were responsible for their own stock, setting levels appropriately to cope with an 8-12 week pandemic. The national stockpile managed by the Establishment for Public Health Emergency Preparedness and Response (EPRUS) could only be used for patients and their contacts.

679. At the outset of the Covid-19 pandemic, France's PPE supply chain system struggled to respond effectively. This was largely blamed on the structures which prevented a centralised response. As commented by one researcher, analysing France's response, "…the French system is complex, and the coordination between the different parts of the care system is known to be weak, making it harder to take a joined-up response involving primary and social care providers and hospitals" (Or et al, 2021).

680. Specifically relating to PPE, the French government had actively reduced stocks after criticism that it had over-reacted to the H1N1 pandemic of 2009. There was a belief that the national stockpile was too high, given that responsibility for the provision of masks was vested at an HCW employer level. 250 million masks were destroyed in 2018 and more were destined for disposal in 2020. As a result of the lack of PPE, specifically masks, some parts of the healthcare industry (dentistry and physiotherapy, for instance) could not work until after the first lockdown. By May, the French government had managed to procure large amounts of PPE, by scaling up domestic manufacturing and procuring supplies on the open market.

681. France's response has been criticised as being:

- too de-centralised, with the government reducing its responsibility for PPE and devolving decisions to a local and employer level;
- too uncoordinated with little communication between primary healthcare providers, hospitals and social care; and
- after the start of the pandemic, overly centralised, with multiple government departments imposing decisions on local providers without consultation or understanding local issues.

682. Although the "too centralised, too devolved" criticisms may seem paradoxical, it could be said that they are a result of a policy which was unprepared for the pandemic and which consequently veered between extremes, both ineffective.

683. At a regional level, the EU's response also faced criticism, not least the length of time it took to respond to the crisis and to calls for help from Italy. "No member state responded to Italy's request and to the commission's call for help," Janez Lenarčič, the European

commissioner responsible for crisis management, is reported as saying. "Which meant that not only is Italy not prepared … Nobody is prepared … The lack of response to the Italian request was not so much a lack of solidarity. It was a lack of equipment" (Boffey et al, 2020).

684. In its defence, the European Commission stated that it quickly moved to:

- set up a common stockpile of equipment ("RescEU") to secure equipment, from ventilators to PPE;
- published a recommendation on conformity assessment to increase the supply of certain types of PPE without compromising standards; and
- required export authorisations for export of PPE outside of the EU.

685. The EU set up a scheme to purchase masks on 28 February 2020 and gloves, masks, coveralls and eye protection on 17 March 2020. Germany and Romania were the first Member States to host the RescEU reserve. From 7 May 2020 the European Commission started to deliver 10 million facemasks to 17 Member States and the UK (EC, 2021).

686. It is debatable whether the EU's joint procurement exercise was successful despite contracts being signed in April. By 22 April 2020 no PPE had been distributed. Regardless of the contracts being signed with suppliers (contracts are signed by member nations), the same pressures on the underlying quantities of PPE in circulation existed.

687. The problems were tacitly acknowledged by the European Commissioner for Crisis Management, Janez Lenarčič, who is also quoted as saying, "When the coronavirus hit Europe, there was a lack of many kinds of medical equipment across Member States. Yet the EU did not have the power or the means to offer equipment; we could only encourage cooperation. Citizens expect the EU to act during a crisis. We all need to be better prepared and learn the lessons. RescEU will be massively strengthened to leave no EU country behind during a crisis" (EC, 2020).

688. Germany's RescEU stockpile has been contracted until the end of 2027 with the requirement to make inventory available throughout the EU within 12 hours of an order being received.

689. The EU's initiative to establish a reserve stockpile was partly driven by the requirement to maintain cohesion within the bloc at a time of great political pressure. It came as many leading partners were implementing export bans on PPE even on an intra-EU basis (Delhomme and Hervey, 2022).

690. Australia's response to the pandemic has received praise (Brookings, 2021) although it exhibited many of the same vulnerabilities as other countries in terms of PPE and healthcare equipment supply chains (Duckett and Stobart, 2020). The government seems to have been able to retain the benefits of centralisation whilst working in a federal structure. A "National Cabinet", meeting weekly, was established comprising the Prime Minister and heads of government of states and territories. To support the National Cabinet, a Covid-19 Response Committee was set up to which, in turn, various task forces reported. At national level, an Industry Capability Taskforce and the Corporate COVID Response group was initiated to manage, "supply chain integrity, the sourcing

quality PPE, and other medical equipment relevant to the Covid-19 pandemic" (Brookings, 2021). Guidelines and practice of PPE use were generally regarded as being consistent across the country. This could be a good template for coordination between UK government and DAs in the UK although a criticism levied at the Australia arrangement was that there was no formal agreement between the national government and state governments setting out roles and responsibilities in the event of a health emergency.

691. Australia was not immune to the global shortages of PPE, price rises or the lack of domestic supply chains which meant that there was a dependence on off-shored suppliers for much of its PPE and healthcare equipment (Basseal et al, 2023). The cost of an N95 mask rose from 1.30 to 38.50 Australian dollars (or $0.93 to $27.55) at the height of the shortages (Brookings, 2021). In addition, its national stockpile had also become depleted due to bushfires that season. In terms of procurement policy, normal processes were suspended under emergency regulations and this has led to allegations that a lack of due diligence of suppliers resulted in the purchase of sub-standard products (Knaus and Conn, 2023) .

692. In terms of inventory visibility, Australia faced similar challenges to other countries. There were tiers of PPE stockpiles including those held at a national, state, Local Health Network (LHN) and hospital level. A report by the South Australian government found, for example, that despite in theory there being an enterprise-wide technology system in place "that there are no system records of PPE held in "imprests" and secondary local stores, which results in a lack of visibility of stock levels at these locations. LHNs are also not receiving sufficient information about PPE items that are in low supply or unavailable." (AGD, 2022). The same report found that LHNs were also sourcing their own supplies of PPE due to a lack of confidence in state stockpiles.

693. One of the recommendations of the report was that the South Australia Health authority should consider the feasibility of upgrading its inventory systems to create visibility of PPE items used and quantities of stock held in imprests. This would be combined with a direct-to-imprest distribution model which involves JIT delivery direct to hospitals from a central distribution facility. The effectiveness of this relatively new system has still to be fully assessed.

694. An interesting initiative undertaken to ensure a guaranteed supply of face masks, was an agreement which the South Australian government reached with a local manufacturer, Detmold (ibid.). The state government contributed 80% of the cost of purchasing 10 mask manufacturing machines and pledged to buy a minimum quantity of masks. The contract held a provision that machines could be repurchased by the government if the company stopped manufacturing masks within three years. The agreement means that the government does not feel the need to stockpile such large amounts of face masks as it has the ability to augment stocks through Quick Response production.

The benefits of direct relationships with manufacturers

695. In my mind, there is no doubt that direct relationships with manufacturers can bring many benefits which do not exist when using an intermediary or a distributor.

- The procuring organisation has a much better visibility of the stock held by the manufacturer and its production capabilities.

- The buyer can develop long term and collaborative relationships with a small number of large manufacturers based on trust and shared goals. This is an essential part of supply chain resilience, with data on volumes and risk being shared.

- The tendering process can insist that the manufacturer has visibility of the suppliers it uses in terms of modern slavery and environmental practices.

696. Informal intermediaries which were used during the pandemic are a symptom of a non-functioning supply chain from a risk perspective, relying on short term and fragile processes.

697. During the pandemic, there was pressure on distributors to serve multiple clients on a "highest price wins" basis. A Spanish buyer of PPE commented, "distributors and dealers urged hospitals to accept their prices at those times, saying that if they did not do it, they could sell the goods to other hospitals which would pay for them" (Morales-Contreras, 2021).

698. Anecdotally, during the pandemic, manufacturers with existing relationships in place with procuring organisations were more likely to fulfil their contractual obligations. This was not necessarily the case when there was no prior relationship in place. Chinese manufacturers were quite capable of selling shipments to the highest bidder, even if they had been earmarked for another buyer.

699. However, the benefits of direct relationships with manufacturers are not unalloyed:

- PPE supply chains can be very long and complex and manufacturers may also act as distributors for other manufacturers. Therefore, using a manufacturer is no guarantee that it will be able to provide complete supply chain visibility;

- A distributor will have multiple sources in a market and therefore will be better able to source products in a time of crisis;

- Due to the commoditised nature of PPE and some healthcare equipment products, there are fewer technical reasons to have a direct relationship with a manufacturer (ie a manufacturer is not required to develop specific products, instead producing them to an international standard). Once this is achieved, the main purchasing criterion is price; and

- Distributors are likely to have much larger inventories of PPE than manufacturers. Manufacturers will want to make and ship products as quickly as possible, whilst the distributor makes its money by ensuring availability.

700. Possibly of more importance than whether PPE and healthcare equipment is sourced directly from a manufacturer or distributor is the relationship which exists. Both types of company are essential to "business as usual" supply chains and the deeper the relationship, the more likely to:

- avoid disruption in the first place;

- overcome short term challenges; as well as

- enable the supply chain to bounce back after a disruption.

701. Supplier visibility is just one of a number of benefits which fostering long term relationships based on quality rather than price can deliver.

702. One of the most important changes which has occurred in the wider supply chain industry is the focus on "direct to consumer" (DTC) strategies by major multinational brands. This may also provide opportunities for the UK healthcare system to enhance the overall effectiveness of its "business as usual" requirements for the supply of PPE as well as those needed in a crisis. It could involve the development of a single platform which could be utilised by all healthcare providers in the UK including Trusts and DAs.

703. In the consumer sector, some manufacturers have started to sell to consumers directly, removing wholesalers, distributors and retailers from the supply chain. This provides a number of efficiencies and benefits for the manufacturer:

    - manufacturers engage directly with end users of their products and this allows companies to better understand buyer behaviour;
    - DTC means that manufacturers can take control of the customer journey from the very start of the sale cycle; and
    - it can create deeper relationships with end-users.

704. This would be an alternative model to the centralisation of buying power within a procurement organisation such as NHS SC. As already detailed, in England, just under a half of PPE procurement is undertaken by Trusts outside of NHS SC buying structures. A DTC approach would improve the efficiency of such arrangements although there may be cost implications. Major PPE manufacturers would increase their understanding of Trusts' PPE demand requirements and more permanent relationships would foster trust in the event of another pandemic.

705. It is important to understand that NHS SC is failing to meet all the needs of its customers and this has resulted in alternative arrangements being established. Although these arrangements may not be as efficient as a "perfect" centralised model, the latter model may take years to achieve, if ever. Therefore, although a fragmented approach to procurement may be sub-optimal compared with a system-wide approach, it may be best to take a pragmatic approach to improve efficiencies on a bilateral basis in the short to medium term. Using new models such as DTC may increase the efficiency and resilience of individual healthcare provider-based PPE supply chains.

706. Enhanced relationships with suppliers could also enable other forms of advanced supply chain management practice such as "vendor managed inventory" (VMI). In this model the manufacturer takes over the entire inventory management role, ensuring that demand is met and stocks replenished. Developing a direct relationship between user and supplier places more responsibility on the manufacturer and has the benefit (for a Health Trust, for example) of cutting out the need for a distributor or NHS SC.

The current state and the future of emergency procurement and how this affects supply chains

The key features of an effective emergency procurement regime

707. As already discussed in this paper, from a supply chain perspective, resilience in the event of a new pandemic will be achieved by:

- Creating visibility of the UK's entire stock of PPE and healthcare equipment regardless of where inventories are held or which organisations are holding them;
- Ensuring appropriate levels and types of stock are held whatever the healthcare emergency may be; and
- Nurturing and developing suppliers of PPE and healthcare equipment, especially those based in the UK.

708. An effective procurement regime should thus be regarded through this "lens".

709. The regime should seek to encourage long standing relationships with known suppliers, on a Framework basis, that is, engaging with pre-approved suppliers. This arrangement is already in place and has been reinforced by the Procurement Act 2023. However, as was evident during the pandemic, whilst it worked sufficiently well on a "business as usual" basis, the model failed to provide sufficient capacity at a time of stress. Many more suppliers should be encouraged to apply for Framework status, meaning that the pool of pre-approved, known suppliers is much larger. This is something the Act seeks to achieve, but progress will need to be monitored on whether the Act will influence NHS Supply Chain's policy on the inclusion of more suppliers in its Frameworks, especially small and medium-sized businesses.

710. Whilst there may be a need for non-competitive "Section 42" awards during an emergency, such measures would indicate that the aim of the Procurement Act in speeding up awards of contract through the normal channels is not working as envisaged. Contracts with suppliers should be in place to ensure that Quick Response production of PPE and healthcare equipment meets the demand for the period between the depletion of national stockpiles and the scaling up of production on the global market.

711. If government ministers take the decision to make non-competitive Section 42 awards, it is difficult to foresee a reason why these should not be awarded to Framework suppliers. This is not to pass comment on the reasoning behind non-competitive awards during the Covid-19 pandemic. During this period, clearly, there was not sufficient capacity with existing suppliers leading to new, informal and unstructured relationships with unknown intermediaries and distributors. However, this should be avoided in future emergencies.

712. As has already been discussed, relationships with suppliers should move from being transactional and adversarial to long term, value-creating and collaborative. They will have a role in managing the upstream supply chain on behalf of the procuring organisation. As Professor Carlos Mena writes in the book "Leading Procurement Strategy", "In this partnership type relationship between buyer and supplier, strategic and

operational capabilities of both parties are leveraged to support mutual planning and joint problem solving efforts" (Mena, 2014).

713. It may well appear paradoxical to develop a procurement strategy which has as its goals the expansion of the supplier base as well as the development of deeper relationships with key suppliers. However, data-sharing technologies will be able to assist by providing the buyer with fast access to more suppliers via, for instance, an e-procurement platform, as well as deeper upstream inventory and production data from established Framework providers. In an emergency healthcare scenario, both approaches can be employed within an overarching procurement strategy.

714. The foundations of good supplier relations will already have been laid during "business as usual" times. However, there will be significant differences during a pandemic which a strong relationship will help overcome:

- it is likely that the negotiating environment will have transformed from being a buyer's market to a seller's, meaning that there will be a lack of pricing leverage;
- there is likely to be asymmetry in the level of market information which the buyer and seller have access to, meaning that the buyer has little visibility of suppliers' costs;
- pressures to procure PPE may result in a lack of focus on quality; and
- if new suppliers are sourced in emerging markets, there may well be cultural issues to overcome.

715. A supplier which is mindful of its long term relationship with a buyer is far more likely to be an effective, flexible and trusted partner than one which is accustomed to negotiating over price alone. As one technology company put it, "The Covid-19 pandemic highlighted the risks of supply chain disruptions, and companies will seek more flexible, collaborative relationships with suppliers to mitigate these risks. This may involve a shift away from purely transactional negotiations and towards more strategic partnerships" (CADDI, 2024).

Author recommendation 28

Procurement organisations should use new technologies to allow them to both extend the number of "Framework" and "known" pre-approved suppliers they work with as well as developing deeper and longer relationships with "core" suppliers. Supplier Relationship Management will be a critical part of increasing supply chain resilience.

In addition, the government should speed up public procurement processes to meet the needs of PPE and healthcare equipment buyers in a way which does not involve ad hoc, non-competitive awards by ministers.

Transparency and accountability

716. Transparency as regards the award of contracts by healthcare procurement bodies is essential to assessing the effectiveness of the UK's preparedness to a future pandemic.

717. Government guidance on transparency requirements recommends that the following information should generally be disclosable under the Public Contracts Regulations 2015:

- the identity of the parties, the contract term, options for extension, overall value (if fixed);
- information setting out the essential obligations of the parties, including, for example, specification/description of services, manner of provision etc; and
- warranties, indemnities and other protections (Cabinet Office, 2023).

718. Despite this, an investigation by the Financial Times alleges that details of £8bn worth of Covid-19 contracts have still not been released in full. A significant proportion of this amount relates to PPE and testing (Plimmer and Wallis, 2023). The contracts relate not just to DHSC or NHS SC spending in England but to that of the NHS Trusts. Although publication of details is not required by law, it is highly recommended and good reason is required if the decision is made to keep details private.

719. The Welsh Audit Office (Audit Wales, 2021) also found that Shared Services did not publish contract award notices within the 30 day required period although it concluded that due diligence checks had been carried out albeit not to the level that would be expected outside a pandemic.

720. In addition to the current publication requirements of contract award notices, it would be beneficial from the perspective of assessing supply chain resilience if the following information were also published:

- the types of relationship which are in place with suppliers;
- their flexibility;
- the scope to scale up or down production or supply;
- delivery terms;
- quality and quantity of products;
- where suppliers are based;
- whether they are manufacturers or distributors; and
- whether they comply with modern slavery or environmental best practice.

Author recommendation 29

Only by gaining a clear understanding of contractual relationships with suppliers will it be possible to judge the resilience of PPE and healthcare equipment supply chains. Although there will inevitably be constraints of commercial confidentiality, there should be an oversight committee to which the DHSC, NHS SC and the relevant procurement organisations report at a UK level.

Summary of Author's Recommendations

Strategic and policy

1. A structure should be established to enable formal communication between the UK government and DAs on PPE and healthcare equipment issues, meeting regularly in business-as-usual times to monitor the market and plan for emergencies. Although DAs will continue to manage their own procurement activities, data-sharing and shared decision making would be encouraged.

2. There should be a single authority responsible for ensuring the resilience of the UK's PPE and healthcare equipment supply chains. Its remit should include visibility of all inventories held in the UK including those of NHS Supply Chain; the DA's centralised procurement organisations; Health Trusts; Primary and Social Care providers; government departments as well as private sector manufacturers, wholesalers and distributors. The authority would act as a "Control Tower", identifying risks; monitoring orders; tracking shipments and assessing inventory levels. The authority would also be responsible for developing a single model to forecast demand and usage rates of PPE which would inform more accurate order policy.

3. A decision should be made by the government on the role of the NHS Supply Chain in the provision of PPE and healthcare equipment in England. Its present status as supplier as well as competitor to the Trusts is ambiguous and leads to confusion, exacerbated in times of stress. It must either take over as a single central procurement organisation, which will require major governmental legislative efforts, or Trusts should be allowed to procure in the way they see best suited for their operations, doing away with the need for NHS SC. If the former is decided, the NHS Supply Chain requires significant investment and must improve its service considerably. If the latter, the Trusts (or ICSs) must be held accountable for ensuring the resilience of PPE and healthcare equipment supply chains in the event of another pandemic.

4. Exercises which test the UK's preparedness for a pandemic should take into account global shortages of PPE and specifically assess inventory levels and scalability of domestic production in the face of export bans imposed by foreign governments, even those regarded as friendly.

5. Through its influence in the WTO, the UK government must encourage major PPE and healthcare equipment manufacturing markets to maintain normal trading relations during pandemics. In addition to this, when negotiating bilateral trade deals, the use of export bans, particularly for critical medical products, should be discussed and, if possible, assurance of supply should be written into any formal agreement.

6. Given the experiences gained from the Covid-19 pandemic, the UK government should work at an international level to produce a single demand model which could be deployed in a future health emergency. Efforts should be made to ensure that relevant data exist which will populate the models. It should not be necessary to develop models from scratch, despite the likely variances in terms of the effects of the disease.

7. The UK government, DAs and industry should invest in research and development related to new, re-usable forms of PPE as part of a circular supply chain. This should involve not just trialling the use of new materials but also innovative cleaning technologies. All stakeholders must be involved in this initiative to ensure future industry adoption and create healthcare worker confidence in the migration from single use products.

8. There should be high level liaison channels between those setting the usage guidelines and those in charge of the PPE/healthcare equipment supply chain response. Although it is understood that technical guidance on the use of PPE will evolve throughout the course of a pandemic, those experts responsible for the changes must be mindful of the impact of their advice on supply chains and must consult with supply chain experts prior to new announcements.

9. Establishing the Parallel Supply Chain as a completely new distribution organisation in a pandemic to centralise procurement and supply as well as provide logistics capacity was a massive challenge and should not be repeated in a future healthcare emergency. Whilst reverting to pre-Covid-19 structures in a "business as usual" environment may have seemed a sensible decision, there is no reason to believe that existing organisations will perform more effectively in the event of a new pandemic. New infrastructure must be put in place which can function as well in a pandemic as it can under normal market conditions.

10. A step towards increasing visibility and supply chain influence would be to create a position and department which would be responsible for not only the "business as usual" provision of PPE and healthcare equipment to the UK market, but in the event of a healthcare emergency or pandemic, would be able to activate a response playbook involving a pre-agreed set of standard operating procedures. It would also be responsible for ensuring the proper utilisation and subsequent replenishing of inventories whether these are PIPP, NHS SC or Trusts, Health Boards etc. Clearly this would be a major task for the UK government to implement alongside DA counterparts.

Supply Chain Management

11. Many of the risks involved in sourcing PPE and Healthcare Equipment stem from the globalised nature of virtual manufacturing networks, including the international nature of transportation and lower levels of control and visibility. When awarding contracts, these risks need to be fully identified in order that they can be mitigated. Attempts must be made to cost them into the procurement process. This would "level the playing field" for manufacturers based in the UK where risks to supply are lower, but costs relating to governance, workers, taxation and environmental impact, for example, are higher.

12. Supply chain planners should treat PPE as a high value product, designing resilience through agility, flexibility and velocity. This is despite the low value nature of the commodity during "business-as-usual" periods. To ensure that value for money is maintained, smarter solutions and new relationships with suppliers will need to be built.

13. The DHSC and DAs should encourage centralised procurement organisations to develop deep, value generative supplier relationships with a small number of key suppliers involving: understanding how suppliers work and their capabilities; managing and

monitoring these suppliers intensively; insisting on data and forecast sharing; and exchanging market knowledge and strategic direction. Supply chain managers must adopt best practices already employed in industry to develop relationships in which there are benefits to buyer and supplier in business-as-usual times as well as during crises.

14. There should be clarity on the terms of reference used by healthcare providers when awarding PPE and Healthcare Equipment contracts. Defining "quality" and ensuring decisions are properly weighted to take into account supply chain resilience will be essential for pandemic preparedness.

15. Suppliers of PPE and healthcare equipment should be located strategically in different parts of the world, to account for the geographic spread of the disease and the impact that this might have on the ability to produce and supply goods (e.g. due to lockdowns or export bans).

16. Procurement organisations should use new technologies to allow them to both extend the number of "Framework" and "known" pre-approved suppliers they work with as well as developing deeper and longer relationships with "core" suppliers. Supplier Relationship Management will be a critical part of increasing supply chain resilience. The UK government should speed up public procurement processes to meet the needs of PPE and healthcare equipment procurers in a way which does not involve ad hoc, non-competitive awards by ministers. This recommendation is also relevant to the DA governments as it would eliminate the need to triage and process unsolicited offers of help from the business community.

17. Only by gaining a clear understanding of contractual relationships with suppliers will it be possible to judge the resilience of PPE and healthcare equipment supply chains. Although there will inevitably be constraints of commercial confidentiality, there should be an oversight committee to which the DHSC, NHS SC and the relevant procurement organisations report at a UK level.

18. The UK government should adopt an approach to stockpiles which combines elements of three potential options. Firstly, strategic stockpiles should be built up to cover emergencies. Secondly, longer term relationships with Chinese and, critically, non-Chinese suppliers must be maintained or developed, even taking into account the possibility that these channels may be rendered ineffectual in a pandemic. Thirdly, some contingency for national production should be put in place. It may be feasible for governments to retain manufacturers to provide PPE and healthcare equipment production capacity which can be switched on at short notice. In the longer term, given the potential for automation and 3D printing in the future, Quick Response manufacturing may become more attractive in this sector as low cost labour becomes less a factor in the production of PPE.

UK manufacturing

19. Whilst it is not possible to reproduce the vast PPE and healthcare equipment manufacturing capacity presently based in Asia within the UK, policy focus should be on developing a small, automated and scalable manufacturing capability.

20. The UK government should enter into agreements with domestic manufacturers which would ensure that they could increase production to cover the period between depletion of national stockpiles and the recovery of global market capacity. Investment in automation will become an important policy goal for the UK government as well as a strategic ambition for UK manufacturing.

21. "Blueprints" should be developed, in conjunction with industry associations, which allow UK domestic PPE and healthcare equipment supply chains to be swiftly initiated in the event of a pandemic. This would involve establishing lists of pre-qualified suppliers, creating relationships and formal lines of communications between government, healthcare equipment procurers and business.

22. If new healthcare equipment is required as part of pandemic response (such as ventilators), efforts should be focused on providing existing medical equipment manufacturers with the resources to scale up production rather than encouraging designs from manufacturers with no relevant experience. Production under licence should be a consideration.

Stockpiles

23. Stockpiles have been recognised by the UK government and DAs as an important tool to supply PPE in the early stages of a pandemic. However, more consideration needs to go into what the stockpile contains and its management and maintenance. Developing a "disease-agnostic" PPE and healthcare equipment strategy involves a much broader focus than just maintaining higher levels of stock. A holistic supply chain approach is required, encompassing demand and demand-modelling; inventory visibility; assurance of domestic and international supply; robust trade and transport systems, all coordinated by a single Control Tower function.

24. Emergency stockpiles should be held on a virtual and rotating basis by distributors and manufacturers rather than in government-owned centralised distribution facilities. This will remove the risk of out-of-date or unmaintained equipment and reduce the cost to the government.

Quality control

25. Quality control issues with PPE and healthcare equipment and the subsequent rejection of many shipments were a result of a breakdown of supplier relationships as well as complexity relating to technical standards. Implementing resiliency measures outlined in this report such as maintaining strong supplier relationships throughout a crisis and simplifying standards should mean it will not be necessary to streamline or reduce border controls and administrative processes to fast-track shipments of PPE at the expense of quality. This will have positive implications not only in terms of ultimately getting more product to hospitals and other health and social care settings, but will ensure more accurate inventory management.

26. Regulatory complexity related to product quality and compliance would be mitigated by the introduction of a single global standard, labelling and trade processes. However, this is not a realistic possibility. Rather, focus should be placed on training all parties involved

in the import of PPE and other healthcare equipment. Not only would this increase the quality of products on the market during a pandemic by reducing sub-standard goods but it would reduce Customs clearance issues which delay shipments at ports and airports.

27. Labelling and testing, along with usage guidelines (eg frequency and appropriate use) have clear supply chain consequences. Use-by dates should be an accurate guide to the safety of a product and its timeline for degradation, if kept in the requisite environment. Re-testing should be regular and taken into account in inventory management systems. The number of Quality Assurance organisations should not be a bottleneck for the approval of PPE and the UK government should "stress test" the sector to ascertain how quickly product could be accurately assessed in a pandemic. Quality standards should be reviewed regularly to make sure that they are set at an appropriate level which safeguards HCWs but does not lead to unnecessary waste. Testing and approval should be science-led, rather than driven either by administrative process or political expediency.

Technology

28. The UK government can play a role in the development of new technologies by fostering an environment of innovation and business investment. It can also help with the adoption of these technologies by supporting skills training, research and development and capital investment tax advantages. For example, this could encourage the adoption of technologies by SME manufacturers in the domestic UK supply chain which would allow them to engage in PPE and healthcare equipment frameworks.

29. An ambitious project should be implemented to map inventory holdings upstream and downstream across the UK. As well as centralised procurement organisations, health and social care providers, this will include manufacturers and distributors. Once this has been undertaken, an Inventory Management System, either new or existing, should be initiated which will allow real time tracking and decision-making through the use of new technologies such as AI. The UK government should use its influence to ensure that all supply chain parties engage with this initiative.

Appendix 1: Types of PPE and Healthcare Equipment

1. *Protective garments* include such items as surgical gowns, aprons, drapes and smocks. They are manufactured to four different standards, Level 1 offering minimal resistance to water and Level 4 providing complete resistance to blood and viral penetration. During Covid, guidance changed on the necessary Levels which had to be used, as the risk of the virus became better understood.

2. *Respirators and Surgical Masks*. There are a variety of respirators and masks offering different levels of protection to the wearer. These include types Filtering Facepiece 2 (FFP2) (similar to the US N95) which offer minimum levels of protection, FFP3 (for use in high risk areas) as well as Fluid-Resistant Surgical Face Masks (FRSM) such as Face Mask IIR. According to government statistics over 3 billion Face Mask IIR were distributed in England between 25 February 2020 and 31 March 2022, compared with volumes of FFP3 163,599,000, the next most popular type (DHSC, 2022). As with many other types of PPE, international guidance changed on the appropriate use of different types of mask throughout the pandemic. For instance, when there were shortages of supply, the use of masks with higher protective qualities was prioritised for situations which involved aerosol generating procedures (AGP) or in settings where there was poor ventilation. (UKHSA, 2022)

3. *Hospital gloves*. Included in this category are examination gloves and, and of more relevance to the Covid pandemic, surgical gloves. The latter are designed to "[be] worn to prevent contamination of the patient during invasive procedures and to protect the hand from exposure to potentially infectious materials" (NHSSC, 2023).

4. *Eye protectors/Medical Goggles*. This category includes goggles, visors and face shields. 183,603,000 eye protectors were distributed throughout England between 25 February 2020 and 31 March 2022.

5. Other items which fall into sub-categories of PPE include: body bags, cleaning equipment, clinical waste bags and containers, "fit test kits", detergent, paper towels and swabs.

6. *Rapid antigen tests ("Lateral Flow") and Polymerase Chain Reaction (PCR) tests* are included within a broader category of healthcare equipment. The main suppliers to the NHS were Chinese manufacturers; Zheijiang Orient Gene Biotech and Acon Biotech being the largest (Feehan, 2022). The first UK Lateral Flow Devices (LFDs) were manufactured by SureScreen in Derbyshire in September 2021 (creating more than 370 jobs). SureScreen previously had been involved in developing technology to test for drug abuse and infectious illnesses. Other UK manufacturers struggled to gain approval to supply the market.

7. *Ventilators*. Given the nature of the disease and its impact on respiratory systems, the availability of ventilators during the pandemic was critical. The manufacture of ventilators is complex, very different from many of the PPE sectors highlighted. It involves a sophisticated combination of electronics, batteries, software, gas delivery systems, monitoring and alarm systems. The complexity of production meant that output of existing manufacturers was very difficult to scale up, leading to multiple manufacturers entering

the market in an attempt to meet demand. This was a worldwide, rather than UK, challenge. As one US post-pandemic assessment commented, “Ventilators were made by Fitbit, Virgin, NASA, and Dyson. But expertise in wearables, flight, and vacuum technology did not translate well to development of a life-support device.” (Branson, 2023)

Appendix 2: Glossary

3D Printing

A manufacturing technique which involves the construction of a product from a digital file by adding successive layers ("printing") of material. It can be used to produce customised, complex products on demand. Also known as "additive manufacturing". It was used during the pandemic to produce small numbers of PPE such as masks and face shields.

3PL

A contract logistics provider, undertaking distribution activities on behalf of a manufacturer or retailer.

4IR

See "Fourth Industrial Revolution"

Ally-shoring

The policy of encouraging manufacturers to source goods or base production in markets which have similar political outlook and shared security goals in order to mitigate the risk of disruption to supply in the event of hostilities. Also known as "friend-shoring" or "friend-sourcing".

Batch Size 1

A manufacturing model in which a single product is made in a single manufacturing process. The product is customised to the needs of an individual, but in high volumes, so-called "Mass Customization". This is largely an aspiration as part of the automation and digital innovations of the "Fourth Industrial Revolution".

Bellyhold

The area in passenger aircraft on the lower deck beneath where passengers are seated which can be used to transport air cargo.

Buffer Stock

Inventory kept on hand over and above forecasted customer demand in case of supply chain disruption events and uncertainties such as transportation delays and other uncertainties which may impact on supply. Also known as "safety stock" or "emergency stock".

Build-to-Order

A manufacturing practice in which production of a good does not start until an order has been received. This reduces the risk of over-production.

"**China plus**"

Sourcing strategies which reduce dependence on China as the main market for supply, utilising suppliers based in one or more additional countries, often located in the Asian region.

Closed Reverse Loop

A logistics operational model which involves the return of a product by a business or consumer to the original manufacturer of the goods. An open reverse loop involves the return of product to a third party organisation.

Collaboration

In a supply chain context, suppliers, customers and relevant service providers (such as logistics companies) share business and product strategies, data and forecasts to increase overall efficiency. This requires not only technological integration but a cultural transformation from a transactional relationship based solely on cost to one which is focused on long term mutual benefits.

Digitisation

The transfer of data from paper-based documentation to electronic. For example, in the transport and shipping industry, this can involve moving from physical signatures on proof-of-delivery forms to digital signatures. This creates efficiencies such as the speed of transfer of data through IT networks and the reduction of errors.

Direct-to-Consumer

A distribution channel employed by some manufacturers which involves selling products directly to consumers rather than through wholesalers, distributors or retailers. This often involves e-commerce sales through websites. It enables manufacturers to better understand customer demand and behaviour rather than the relationship being governed by a third party.

Distribution Centre

An interface between the manufacturer and end user, often managed by a 3PL, where product is held on a short term basis before final delivery. Value added services such as postponed manufacturing are often provided at a distribution centre.

Ex works

An international trade term which is used to define the agreement between a buyer of goods and the seller. In an ex-works agreement, the buyer takes ownership of the goods at the supplier's factory gate and arranges its movement to the destination. The buyer bears full shipping costs, responsibility, insurance and risk. The opposite to DDP.

Emergency Stock

See "Buffer Stock"

Fourth Industrial Revolution or '4IR'

Defined by the World Economic Forum (WEF) as "a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres". It builds on the digital revolution created by computers and electronics from the mid-20th century to transform peoples' lives and the way businesses operate through the application of artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing.

Intermodal yard

A rail yard where containers are transhipped from rail wagons by crane to trucks and vice versa. Intermodal solutions combine the efficiency of moving containers long distances by rail with the flexibility and speed of first and last mile collection and delivery by truck.

Internet of Things (IoT)

The network of objects, products, vehicles and appliances embedded with sensors (see "low cost sensors") that allows data collection and exchange with devices via the internet. Data is transferred without human intervention to facilitate monitoring and automated decision-making.

Inventory

Inventory includes raw materials, components, unfinished goods and/or end products. Inventory refers either to individual warehouses, to storage areas or to all of the articles that a company has in stock. Inventory is an international term used interchangeably with "stock" which is more often used by UK companies.

Just-in-Case

Traditional manufacturing technique in which production takes place at scale to minimise set up costs and reduce cost per item made. This results in large inventories with associated disbenefits of unsold stock; financial costs of capital tied up in inventory; redundancy; obsolescence; risk of theft and deterioration of product. However, it mitigates the risk of stock outs and disruptive supply chain events.

Just-in-Time (JIT)

The delivery of materials needed for production precisely at the time they are required, eliminating the need for unnecessary stockholdings within the supply chain. It reduces the cost of inventory holding and the other risks outlined in Just-in-Case. It requires far more supply chain precision to ensure there are no stock outs and relies on super-efficient transport networks to make sure production schedules are maintained. Hence, businesses have found that JIT production and delivery is highly vulnerable to supply chain disruptions.

Kanban

A system originating in Japan which facilitates Just-in-Time manufacturing by providing supply chain managers with visual prompts of when materials are required and how much to be ordered. It reduces the level of inventory needed.

Lean Inventory Strategy

The elimination of "waste" in a supply chain. Waste is defined as anything or any process which does not add value to the customer including over-production, excess inventory, unnecessary work (such as multiple and redundant data entry), over-regulation, poor supply chain visibility or inefficient transport.

Logistics

There are multiple definitions of logistics from the specific to the more general. 1. The time-related positioning of resources to meet user requirements. 2. The process and coordination of products, raw materials, and services across the supply chain. 3. A general term used to describe the process or management of the physical movement of goods or the companies involved in this process.

Low cost sensors

Small, cheap electronic devices which can be attached to products and packaging to collect and transmit data on usage, the environment in which it is stored or status in the supply chain. They facilitate automation within the "Internet of Things" and create data which can be analysed by Artificial Intelligence to make more effective supply chain decisions.

Near-shoring

Near-shoring is the transfer of business processes to companies in a nearby country, often sharing a border with your own country, where both parties expect to benefit from one or more of the following dimensions of proximity: geographic, temporal (time zone), cultural, linguistic, economic, political, or historical linkages.

Near-sourcing

Near-sourcing is a term used to describe a business strategically placing some of all of its operations close to where its end-products are sold. Typically, the term is contrasted with and used to highlight the reversal of the trend to outsource low-wage manufacturing operations to developing nations.

In cases of near-sourcing, the business is often responding to rising costs in supply chains as well as rising costs associated with sourcing labour in developing nations. Aside from mitigating the uncertainty of rising costs associated with outsourcing to offshore locations, there are some other advantages. These include cultural barriers, proximity, time-zone constraints and skill surplus where available.

Original Equipment Manufacturers (OEMs)

A company which designs and sells products under its own brand but which are assembled from components or units produced by out-sourced manufacturers, usually in a "tiered" system. See "Tier 1 Suppliers".

Phytosanitary checks

These take place at border controls to ensure imported plants are free from dangerous pests and diseases.

Primary Distribution

Primary Distribution is the movement of goods from suppliers into a production process, manufacturing facility or storage facility.

Quick Response Manufacturing

A production strategy which focuses on the reduction of lead times in manufacturing, making an organisation more responsive to changing market conditions.

Secondary Distribution

Secondary Distribution is moving goods from the production process, manufacturing facility or storage facility to the end user.

SKU

A number assigned to a particular product for the purpose of inventory management based on its relevant attributes. It is designed to inform a company on inventory levels and product assortment, balancing the threat of stock-outs with cost management.

Spot Market

A 'spot market' is a market in which short term placements of orders are negotiated between buyer and seller at a specific price point reflecting the market conditions of the time.

Stock

See "Inventory"

Safety Stock

See "Buffer Stock"

Supply Chain

A supply chain is a system of organisations, people, activities, information, and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials, and components into a finished product that is delivered to the end customer. Logistics companies ensure that goods move along the supply chain.

Supply Chain Management (SCM)

Supply chain management spans the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption. It is also defined as the "design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronising supply with demand and measuring performance globally."

SCM draws heavily from the areas of operations management, logistics, procurement, and information technology, and strives for an integrated approach.

Tier 1 suppliers

Out-sourced manufacturing companies which supply modules or part assembled units directly to an Original Equipment Manufacturer (OEM) for final assembly and distribution to the end-user. Tier 2 suppliers will provide intermediate goods or components to Tier 1 suppliers and so on. The more tiers in a supply chain the more difficult it is to have visibility of inventory levels, ethical or environmental practices at the lowest level of production.

Tracking and Tracing

Tracking and Tracing (also known as Track and Trace) is an electronic system used to locate shipments. With tracking, the current status of a shipment is determined - answering the

question: “Where is a consignment right now?” Tracing describes the possibility of being able to reconstruct retroactively where a shipment has been. The aim is to document the route taken by a consignment and all the relevant events (incorrect handling or loss, delays, etc.).

Transhipment/Transloading

The process of transferring a shipment from one mode of transport to another – road to rail for example.

Unbundling

The process of separating production processes as a precursor to out-sourcing those which are no longer considered core to a business.

Value Chain

The process by which value is added to products at every manufacturing stage from the extraction of raw materials to the delivery to the end-user. This usually involves tiers of specialist suppliers processing materials and producing intermediate goods before final assembly. It often takes place on a global scale, with many stages occurring in multiple countries, termed the Global Value Chain (GVC).

Vendor Managed Inventory (VMI)

A supply chain contract in which the supplier takes over the management of inventory from its customer. Having direct access to usage data, this allows the manufacturer to schedule its own production more efficiently as well as manage logistics and prevent stock outs. Meanwhile, the customer (for instance, a healthcare provider) would benefit from lower levels of administration (such as the need for purchase orders).

Virtual Manufacturing Networks

Modern manufacturing systems which consist of multiple independent suppliers working for an OEM which has chosen to unbundle and out-source production processes in order to focus on design and marketing capabilities and reduce invested capital. Data sharing and robust transport networks are critical to their success due to the high level of inter-company transactions and freight movements.

WMS (Warehouse Management System)

A WMS is IT software which controls the movement and storage of materials within a warehouse and processes associated transactions, including shipping, receiving, putaway and picking. A WMS monitors the progress of products through the warehouse.

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Annex 1: Pre-pandemic simulation exercises and associated reports

Taken from pages 181 to 191 of the Inquiry's Module 1 report (UK Covid-19 Inquiry, 2024):

Exercise name	Year	INQ reference	Available at
Exercise Shipshape	2003	INQ000235217	https://covid19.public-inquiry.uk/wp-content/uploads/2024/02/15100905/INQ000235217.pdf
Exercise Goliath	2003	INQ00020664	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/21172845/INQ000206664-1.pdf
Exercise Bennachie	2004	INQ000187903	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/21172425/INQ000187903-1.pdf
Exercise Winter Willow	2007	INQ000128977	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/21180605/INQ000128977.pdf
Exercise Taliesin	2009	INQ000128976	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/21173642/INQ000128976.pdf
Exercise Cygnus	2014	INQ000128979	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/21173035/INQ000128979-1.pdf
Ebola Preparedness Surge Capacity Exercise	2015	INQ000090428	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/22155047/INQ000090428.pdf
Exercise Valverde	2015	INQ000022722	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/22154747/INQ000022722.pdf
Exercise Alice	2016	INQ000090431	https://covid19.public-inquiry.uk/wp-content/uplo

			ads/2023/07/22153252/INQ000090431.pdf
Exercise Silver Swan	2016	INQ000103012	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/21173540/INQ000103012.pdf
Exercise Cygnus	2016	INQ000022792	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/22161406/INQ000022792.pdf
Exercise Broad Street	2018	INQ000090442	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/22153635/INQ000090442.pdf
Exercise Iris	2018	INQ000147839	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/21173855/INQ000147839.pdf
Exercise Pica	2018	INQ000023034	https://covid19.public-inquiry.uk/wp-content/uploads/2023/07/22153255/INQ000023034.pdf

Annex 2: List of materials provided by the Inquiry

INQ000492085	Witness Statement of Paul Webster on behalf of Supply Chain Co-ordination Limited, dated 27/06/2024.
INQ000528391	Witness Statement of Jonathan Marron (Director General of Primary Care & Prevention) on behalf of DHSC, dated 16/12/2024.
INQ000527714	Witness Statement of Andrew Mitchell, former Director General of the Department for International Trade, on behalf of the Department for Business and Trade, dated 11/12/2024.
INQ000506956	Witness Statement of Andrew Slade on behalf of the Welsh Government, dated 30/09/2024.
INQ000498141	Witness Statement of Caroline Lamb (Director General for Health and Social Care, Scottish Government), dated 21/10/2024.
INQ000497031	Witness Statement provided by Gareth Rhys Williams on behalf of the Cabinet Office, dated 05/07/2024.
INQ000410867	Witness Statement of Professor Susan Hopkins, Chief Medical Advisor on behalf of the UK Health Security Agency, dated 31/01/2024.
INQ000521969	Witness Statement of Gordon Beattie (Director of National Procurement) on behalf of NHS National Services Scotland, dated 21/10/2024.
	Witness statement of Dame June Munro Raine on behalf of the Medicines and Healthcare products Regulatory Agency (MHRA)
INQ000521972	Witness Statement of Sarah Collins (Commercial Director) on behalf of THE UK Health Security Agency, dated 03/12/2024.
INQ000553497	Witness Statement of Antony Gerard Mannix, former Chief Executive of Clipper Logistics Plc, dated 14/01/2025.