The Power of Purpose – Lessons in agility from the *Ventilator Challenge*

Abstract

Purpose: COVID-19 has shaken views of what is normal and what is possible, raising questions about conventional norms, ways of working and our understanding of agility. This paper responds to calls for empirical research of supply chain capacities in times of crisis and offers a unique perspective on agile procurement and supply chain management from a case study of the *Ventilator Challenge.*

Method/Approach: A descriptive case study was undertaken, adopting an inductive approach. Interviews were conducted with the major stakeholders tasked with the design, sourcing and assembly of ventilators.

Findings: Findings are delivered across four key areas: context, procurement and supply chain management, technology and culture, and environment. Key challenges and enablers are discussed, highlighting the critical roles of trust, empowerment and enabling technologies in the construction of an entirely new ventilator supply chain, from scratch, in five weeks.

Contribution: This paper delivers contributions for both academic research and practice. The case study offers rich new insights relating to procurement in times of crisis, contributing to efforts to advance beyond outdated approaches for resilience in literature. Practical contributions arise in highlighting the significance of adapted sourcing and recruitment, technology, collaboration, people and power of purpose in enabling agility and achieving the impossible.

Key words: COVID-19, *Ventilator Challenge*, Agile Procurement, Trust, Collaboration, Empowerment

1. Introduction

In January 2020 The World Health Organisation reported a severe flu-like illness infecting citizens in the city of Wuhan in China's Hubei Province and recommended curtailment of travel to the area. Drawing upon experiences from the 2002-2004 SARs and 2014 Ebola outbreaks, the authorities acted swiftly to place the city in lockdown in an effort to contain the infection. At that time there were only two cases of Coronavirus identified in the UK, now ubiquitously known as COVID-19. The human impact of the pandemic is apparent, by December 2020, there were 69.7m confirmed cases globally and over 1.5m deaths from the disease. The

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pandemic immediately disrupted key industrial sectors, bringing into sharp focus the vulnerability of global production networks and supply chain hubs in China, the main manufacturer of medical supplies. To reduce contagion production sites closed at a time when global demand for life-saving ventilators soared creating a worldwide shortage.

In the UK there were two main companies that manufactured ventilators (Penlon and Smiths Medical), neither of whom had the capacity to meet the increased demand. To address the anticipated shortage, the UK Government sought assistance from prominent UK technology and engineering businesses from the aerospace, automotive and medical sectors. The *Ventilator Challenge* was launched on the 16th March, 2020 with a wartime-style "call to arms" to address this national emergency and produce 30,000 ventilators within eight weeks. This required creation and production of approved products and setting up production facilities on a scale that would normally have taken years.

A consortium began to evolve, led by Cabinet Office (the corporate headquarters for the UK government) and the Department of Health and Social Care (DHSC), tasked with the execution of a two-pronged strategy: (1) scale up production of existing ventilators manufactured in the UK; and (2) design, source and manufacture new ventilators, in the UK and, if necessary, overseas. PA Consulting was appointed as programme managers and co-ordinated the development of 15 separate design programmes within three weeks, each with their own constellation of companies who had responded to the Government's call. This amounted to a collaborative effort on an unprecedented scale, with 50 businesses, ranging from the UK's largest engineering businesses to specialist manufacturers of precision components, pooling their expertise and capacity to source over 40 million components from 21 countries. In the case of one of these programmes, the Parapac 300, manufactured by Smiths Medical, which is the focus of this case study, four new ventilator production lines were built, from scratch, within five weeks.

Key consortium members assigned to the project were: Smiths Medical, who provided essential technical support in relation to the design and manufacture of the Parapac 300 ventilator, which they have been producing for more than 20 years; PA Consulting, who played both a key co-ordinating role in relation to product design and ensuring compliance with quality and safety standards on the assembly lines; Rolls Royce, who led on sourcing and procurement and established a production line for the new device at the Smith Medical facility in Filton;

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Accenture, who built the Enterprise Requirements Planning (ERP) system and managed transactions; Formula 1 McLaren and Williams, who worked on the re-engineering and production of test boxes; GKN Aerospace, who supported the assembly of ventilators at two of their facilities, in Luton and Cowes; and DHL, who were responsible for logistics. The timeline from sourcing to assembly is illustrated in Figure 1.

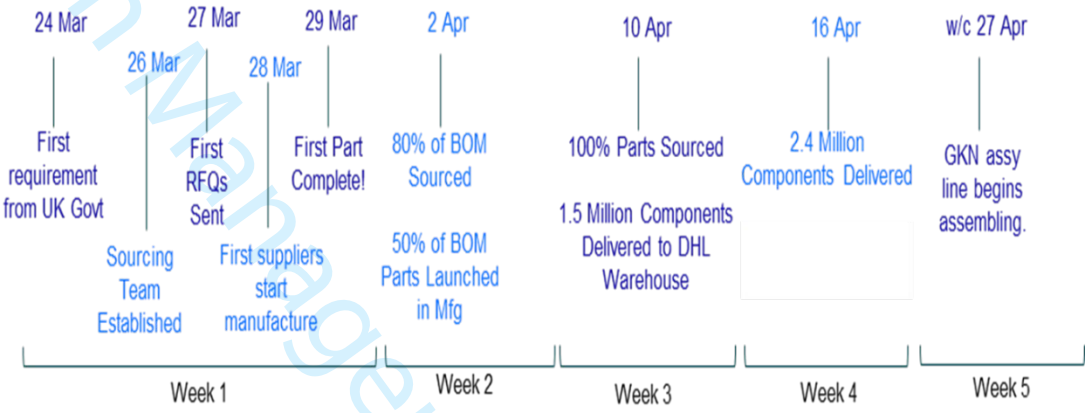

Figure 1 – Project timeline from sourcing to assembly

Within days of the launch of Ventilator Challenge Rolls Royce, who led the procurement for the new Parapac 300 supply chain, established the sourcing team, who used their global networks to identify potential component suppliers. The first requests for quotes (RFQs) were sent within 24hrs, manufacturing of new components began 24hrs later and the entire Bill of Materials (BOM) for the manufacture of the Parapac 300 was sourced by April 10th. 2.4 million components were delivered to DHL, the logistics partner, over the next two weeks and assembly of the new Parapac 300, by GKN aerospace, began one month after the project was launched.

The consortium worked without constraints, as the Government committed to accept all ventilators manufactured until the end of June. Post-June, it was arranged that Smiths Medical would buy any remaining parts for their existing production facility, and the NHS would hold surplus stocks of the new ventilators to improve ability to cope with future spikes in infections. The insights and learnings from this extraordinary effort are many and varied and will, in time, inform both theory and practice in across numerous organisational functions and business processes. This study is focused on agility in procurement and supply chain management, with detailed insights generated from a case study of one of the projects that involved ramping up

production of the ventilator manufactured by Smiths Medical, who had neither the manufacturing capacity nor the supply chain capability to increase production of its Parapac 300, from 60 units a week to the required level of 140 a day. This called for the establishment of a new supply chain from scratch, to manufacture the Parapac 300 using components sourced from alternative suppliers, minimising disruption in the existing supply chain and enabling the targeted increase in production within 5 weeks.

COVID-19 has shaken views of what is normal and what is possible, raising questions about conventional norms, ways of working and the extant literature on agility in procurement, and supply chain management. The case study contributes to theory and practice across four key areas: context, sourcing and procurement, technology and culture and environment. This brings to the fore: the nuanced relationship between risk management and trust in the delivery of a complex project at unprecedented speed under unprecedented levels of uncertainty; the role that enabling technologies play in achieving the impossible for the 'common good'; and the significance of organisational culture, leadership, empowerment and mind-set as critical enablers of agility in times of disruption.

Following an inductive approach, semi-structured interviews were conducted with stakeholders involved in various parts of the case study, informed by the literature and seeking answers to two research questions:

(1) What were the key challenges and how were they overcome? and
(2) What lessons can be learned for inform theory and practice post-Covid?

The paper comprises five sections. Section two outlines the case study methodology adopted for this study. Section three presents the key findings - major challenges and the key enabling factors, with particular attention to the approach adopted for the sourcing and procurement of components for the new supply chain. Section four links the key findings from the case study to the literature and the paper concludes with a summary of the contribution to theory, implications for practitioners, methodological limitations and recommendations for further research. The unconventional structure of the paper reflects the retrospective case study analysis, which was undertaken during the exceptional circumstances of COVID-19.

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2. Methodology

Case studies are a prominent and often sought-after method in supply chain research (Seuring, 2008). This is in part due to their propensity to permit direct access to and explication of real-life events (Yin, 2018) and operational activities (Voss *et al.,* 2002, Reis *et al.,* 2018). With unparalleled circumstances across all aspects of business and operations (Baveja *et al.,* 2020), COVID-19 offered a novel context for empirical, event-based supply chain research (van Hoek, 2020). The *Ventilator Challenge* presented a unique opportunity for such research. Thus, adopting an inductive approach to the research questions, a descriptive case study was undertaken of the Parapac project, exploring: (1) the role played by consortium members; (2) the major challenges and how they were overcome; and (3) lessons learned. The research was conducted over a period of six months, from June to November 2020 and comprised three stages: data collection, data analysis and validation and reflection.

2.1 Data Collection

Case study data collection is not dissimilar to other qualitative methods (Yin, 2018), strongly reliant on interviews (Seuring, 2008). As the consortium was considered the unit of analysis, interviews were conducted with the major stakeholders tasked with the sourcing and assembly of the Parapac 300, ensuring that the case study was informed by multiple perspectives. In total, sixteen interviews were conducted with fourteen participants, most of whom held senior positions in their respective organisations (see Table 1) and were directly involved in the project: two from Smiths Medical (ventilator design): seven from Rolls Royce Aerospace (sourcing and supply chain); two from Accenture, a global professional services company with leading capabilities in digital, cloud and security (ERP system and data management); one from DHL (logistics) and two from PA Consulting (Programme Management, Design and Certification). The prevalence of personnel from Rolls Royce reflects the lead role they played in sourcing and procurement – the primary focus of this case study.

Table 1. Interviewees

Consortium	Respondent	Position
Rolls Royce	RR.1	Chief Procurement Officer
Rolls Royce	RR.2	Supply Chain Operations Supplier Executive
Rolls Royce	RR.3	Head of Procurement Excellence, Civil Aerospace

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Rolls Royce	RR.4	Buyer – Raw Materials
Rolls Royce	RR.5	Supplier Relationship Manager
Rolls Royce	RR.6	Strategic Buyer
Rolls Royce	RR.7	Digital Manufacturing Director
Accenture	A.1	Managing Director - Aerospace and Defence
Accenture	A.2	Senior Manager - Supply Chain Operations
Smiths Medical	SM.1	CFO Medical Division
Smiths Medical	SM.2	Head of Operations
DHL	DHL.1	Vice President Automotive (Tier 1 & Niche)
PA Consulting	PAC.1	Technical Consultant
PA Consulting	PAC.2	Partner

All of the interviews were conducted online, due to lockdown restrictions, and the majority were held between June and September 2020. All of the interviews were recorded and, on average, lasted just under one hour. In addition, three 'follow-up' interviews (RR.1, RR.7 and A.2) were conducted several months after completion of the study. Not only did this support respondent validation of the final draft of the case study, it also allowed for greater reflection as the *Ventilator Challenge* had reached its conclusion. This was particularly important for explicating the 'lessons learned'.

The use of core questions across all interviews is recommended to establish a case study protocol (Voss *et al.,* 2002, Yin, 2018). Given the inductive nature of this case study, interviews were open and conversational. Nonetheless, 'core' questions were guided by the three key topics defined above (the role played by consortium members, the major challenges and how they were overcome, and lessons learned). Specifically, all interviewees were asked to describe their role in the consortium, explain the approaches adopted to overcoming challenges encountered and identify the lessons learned, for themselves and their organisations. Alongside the interviews, secondary data from internal company presentations, emails, on-line articles and reports were consulted to provide additional insights and contextual detail. This is common practice in case study research in operations and supply chain management (Voss *et al.*, 2002, Barratt *et al*., 2011), contributing towards the triangulation of the primary evidence.

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2.2 Data Analysis

The value of the data was realised in the analysis undertaken to identify the key lessons learned and implications for theory. Thematic analysis was undertaken manually, with an inductive approach preserving the richness of the data and the uniqueness of the case. This meant that 'themes' were guided solely by the data and defined by the research team collectively following completion of data collection. Having defined key themes the researchers then coded the data independently, before comparing and refining results. Exercising intercoder reliability, the final codes required agreement from three of the four researchers to be included in the paper and are presented in Table 2.

Table 2 Emergent Themes and Data Coding

Theme	Codes	
	Challenges	**Enablers**
Context	• COVID-19: national emergency • Speed: urgency, rapid change, responsiveness	• Purpose: collective belief, determination, common good, wartime effort • Serendipity: spare capacity, volunteers
Sourcing and procurement	• Safety: compliance with MHRA standards • Uncertainty: production capacity, bottlenecks • Complexity: specialist components • Risk management: Intellectual Property, Quality Assurance • Supplier selection: evaluation, recruitment	• Governance: project management • Collaboration: trust, respect • Agility • Flexibility • Functional expertise and experience
Technology	• Visibility: data capture, analysis and sharing	• ERP • Control Tower • Communication: continuous, open multi-channel, social media
Culture and Environment		• People: mindset, motivation • Leadership: authority, teamwork, empowerment, • Collaborative relationships

2.3 Validation and Reflection

Respondent validation is recommended where multiple sources of information have been used, allowing respondents to check the accuracy of data gathered and add additional insights based on their own reflection (Yin, 2018, Torrance, 2012). For this purpose, a draft of the case study

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was circulated to all contributors for review. Whilst minor comments and revisions were forthcoming, all interviewees agreed the draft offered an accurate account of the consortium's activities, the major challenges and the key lessons learned. Following this validation, a retrospective literature review was undertaken, guided by the key themes from the coded data, to identify the implications for theory. Leaving the review of the literature until after the data analysis is consistent with recent calls for more creative approaches to the use of literature reviews (Snyder, 2019) and is similar to the integrative approach to literature reviews adopted in other areas of management research (Covington, 2000, Gross, 1998), Mazumdar *et al.,* 2005), where the goal is not to cover all literature but to combine perspectives to create knowledge. This is the case here, where the opportunistic collection of data during the COVID-19 disruption encouraged retrospective linking of empirical findings to existing literature for new insights relating to resilience and agility. It also prevented the use of assumptions, leading interviewee accounts of what transpired and supported reflection and consequently explication of theoretical implications.

3. Key Findings - Ramping up production of the Parapac 300

The task was to design, build and implement a solution that would allow production of the Parapac 300 to be ramped up from 60 units a week to 140 a day within 5 weeks, whilst complementing not disrupting the existing production at the existing Smiths Medical facility in Filton.

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The key findings from the interviews with consortium members are presented in the following four sections, using the key themes that emerged from the data coding – context, sourcing and procurement, technology, culture and environment. In each section we discuss the key challenges and the critical factors that enabled the consortium to overcome them. Many of the challenges identified would be expected in any complex project environment but were exacerbated in this case by the accelerated pace of decision-making in organisations with no prior history of working with each other.

3.1 Context

Due to the unique circumstances of the project speed was prioritised over cost, creating potential risks from operating at unprecedented speed. This was mitigated via the formation of a "Technical Design Authority" (TDA), a multi-disciplinary team set up by the Department of

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Health and Social Care, comprising NHS clinicians, the Medical and Healthcare products Regulatory Agency (MHRA) and PA consulting. The TDA dynamically monitored demand, evolving clinical need, relative product functionality, delivery timescales and cost of supply, with all parties required to work on an open-book basis. This enabled regular review of requirements, reprioritisation of resources and ensured that regulatory, QA specifications and testing standards were maintained.

From a human perspective, the response from the consortium members to "*serve the nation*" at a time of extreme crisis was overwhelming. People worked around the clock for weeks, often in parallel with their day-to-day duties to facilitate speedy delivery of the ventilators. This placed considerable strain on consortium members who were often required to abandon established processes in order to make decisions at unprecedented speed. The Government's commitment to cover all reasonable costs removed most, if not all, of the financial risks associated with involvement and the downturn in economic activity. Whilst these factors created capacity with the consortium members to facilitate rapid response, they did not diminish the scale or complexity of the task. The enforced lockdown created additional challenges with respect to co-ordination, collaboration and communication between organisations, some of whom had little or no prior knowledge of the design, production or sourcing requirements for ventilators. These organisations were driven and united by a common goal – to save lives.

With the core team in place, the project rapidly gained momentum. *"The key factor was around one purpose- saving lives - that energised and gave real direction to the project"* (A.1). Time was of the essence and each consortium member was "*playing to their strengths… we did not have time to sort out everything…we learned as we went along*" (RR.1).

Three key principles were embedded into processes and structures - speed, agility and compliance with industry standards. Speed and agility were essential to ensure rapid deployment, and light touch processes for ease of adoption and to simplify workflows. However, at no stage could this result in comprising the stringent quality assurance processes in place for medical devices *"… notoriously difficult to manufacture and have to be completely quality assured. It is so different from other technological appliances in terms of regulation, training and certification requirements, manufacturing technique and certification"* (SM.2).

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The procurement task was immense. Rolls Royce led the sourcing and procurement of over 288 unique parts - small and complex with extremely tight tolerance made from plastic, brass, stainless steel and aluminium. Importantly, this is unlike the large-scale commodity sourcing to which Rolls Royce were accustomed and involved sourcing from over 100 suppliers, 75 of which had no prior involvement with the production of ventilators and no trading history with Rolls Royce. Over 200 Rolls Royce employees volunteered for the project, of whom 50 were involved with sourcing and procurement.

The entire project was complicated and there were challenges at all stages with respect to achieving the level of agility required to meet the project objectives, and the implications of working at an unprecedented pace with the entire country in lockdown. All of the people involved were working remotely and the whole project was undertaken via virtual communication. The lockdown imposed many strains on individuals who continued working, while looking after children and managing home schooling. Prior to COVID-19, home working was uncommon with usually at any one time at least 70% of staff occupying office buildings. In the early days of the project there were issues with systems integration, which comprised supply chain visibility and the accuracy of demand forecasts, with inevitable consequences for the availability of components. However, these were rapidly resolved and with the widespread adoption of Microsoft Teams, effective communication was maintained throughout the project.

3.2 Sourcing and Procurement

The first step was the creation of the bill of materials (BOM) for the Parapac 300, without which the sourcing of new components would not be possible. This meant that Smiths Medical had to hand over their design, comprising the original (2D) drawings and the detailed specifications, from which the BOM for the new supply chain could be derived "*We did everything we could to try and help, purely altruistic. I have never seen anything like it. This meant giving up our design and handing over our IP*" (SM.1). Everyone involved signed an NDA but there was no time for Smiths Medical, or anyone else, to ponder over the commercial risks associated with working so openly.

PA Consulting engaged Williams F1 to reverse engineer the Parapac 300 from the original 2D drawings and build a prototype in 3D CAD which was validated by *"engaging their supply chain to rapidly prototype the ventilator, machine the parts and bring them to Smiths Medical*

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for assembly, to ensure that assembled product would pass all the regulatory tests with which the new production lines would be confronted (PAC.1). This was achieved within 10 days *"lightening pace as Williams were able to disseminate the drawing and distribute the task between dozens of engineers, most of whom were working from home*" (PAC.1).

In the process, PA Consulting identified 10 critical (high risk) components that were removed from the procurement process for the bulk of the parts and sourced directly by PA Consulting in consultation with Smiths Medical. This served three purposes: first it protected the strategic relationships that Smith Medical had developed over many years of working with a small number of highly specialised manufacturers from around the world; second, it reduced the likelihood that the ramping up of production would be constrained by a shortage of these critical parts; and third, it reduced the likelihood of problems with quality management and regulatory compliance at later stages in the assembly process.

3.2.1 Setting up the Buyer Teams

The organisational structure of the procurement process adopted by Rolls Royce is illustrated in Figure 2.

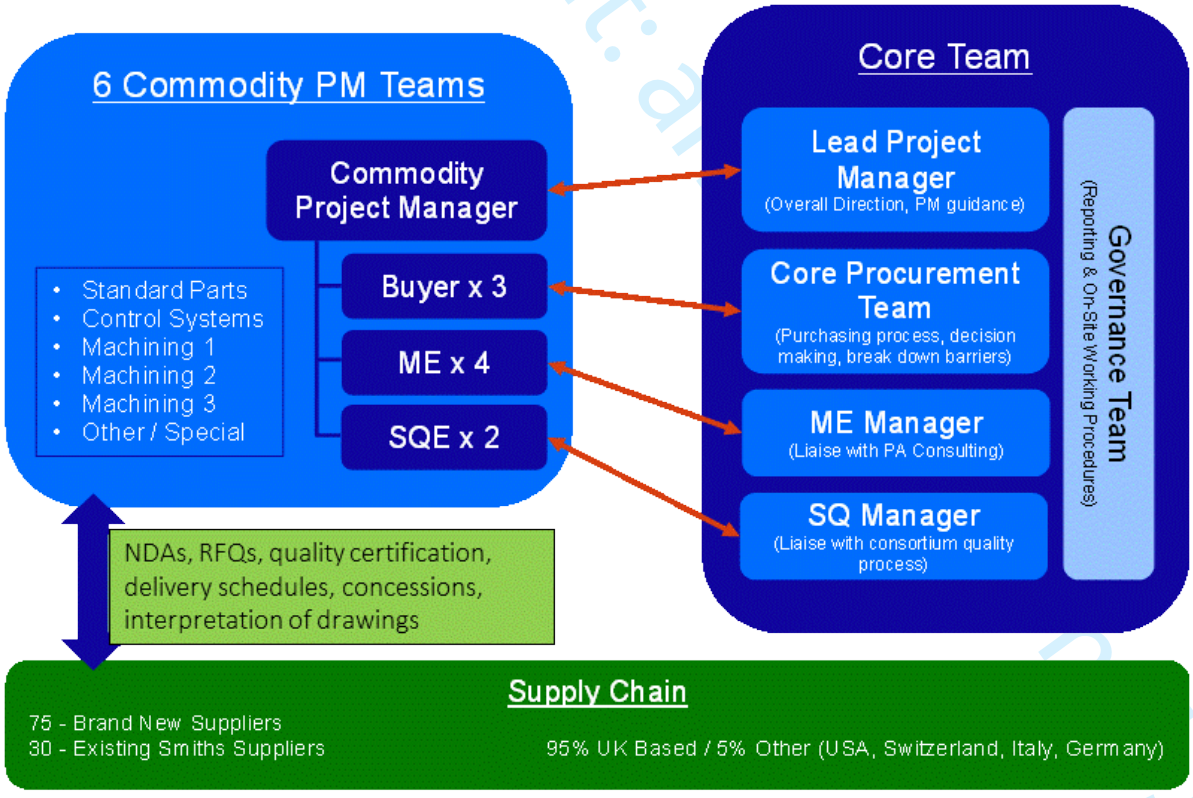

Figure 2 – Procurement Structure

The buying team broke down the ventilator parts in to six commodity categories and aligned resources around the six different commodities "*standard parts like nuts and bolts, control systems, three machining categories and a special category*" (RR.4). Each team comprised two safety and quality engineers (SQE), four manufacturing engineer (ME), three buyers and a commodity project manager who alongside PA Consulting undertook the supplier approval processes, in consultation with Smiths Medical "*PA Consulting had design authority and did the supplier approval, which was really important, and Smiths Medical duplicated their design authority to facilitate checking"* (A.2).

In normal circumstances, sourcing suppliers requires checks and balances that can take from six to twelve months. By the afternoon of the first day, Thursday March 26th, 2020, they had already started to bring the buyers together and set up project management and governance frameworks. "*Operationally we had very good governance and this supported the cadence*" (RR.2).

This new situation demanded different approaches to search for and source completely new suppliers. The quickest way was to use Rolls Royce internal social media channels. In the first instance Rolls Royce procurement reached out to management, procurement and civil aerospace teams requesting they explore their own networks for anyone who had experience with medical devices. From a couple of contacts a core team was established. A member of the 'fast make' team had suppliers who made small precision products that could be transferrable to ventilator production. Another person responded saying "*I felt that this is such an important thing, I'm so passionate about it. I'm really good at analysis and analytics; let me know if I can help*", whilst another, who became the Resource Manager (RR.3), replied "*I want to help. I don't have a ton of time, but how are you going to manage the resources on this*?".

The core procurement team was created from these initial communications. A video was released via the Rolls Royce leadership team on WhatsApp to about 100 people and ended up being sent out to the whole company calling for buyers to help the team "*I needed as many buyers as possible… we started getting buyers coming and offering to help… I had buyers from North America reaching out*" (RR.3). On an individual level, this was a massive undertaking with many risks attached and so many questions to answer, *"we're going to order all these parts, then we're going to have to chase them…. Do we have the resource and the risk analysis*

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to do this… what about the contracting and the IP?" Rolls Royce senior management were completely on-board and in no doubt that "*it was going to happen*" (RR.3).

3.2.2 Supplier Selection

It was essential to establish structure and rhythm as quickly as possible**.** Operations started to stabilise once a "common language" was formed; this included defining unique identifier codes for suppliers, as well as articulating consistent planning assumptions such as Minimum Order Quantities (MoQs), buffer stock levels and lead times. At the beginning "*there were a lot of logistical things that I think we did not anticipate… the handling and logistics associated with the parts I think was a bit more complicated*" (A.2). Once structures had been established, minimising subsequent manual intervention to the data was key to maintaining speed.

The decision was made at the outset to avoid using the existing supply base, for fear of disrupting production at Smiths Medical "W*e did not want to swamp our supply chain if we messed with it we would not be making even 50 a week. We need needed to set up a completely new supply chain. That is effectively what we set out to do. We tried not to make it single sources and that is what Rolls Royce went off and did. They worked with our quality and regulatory body to make sure we approved the new supplier's into it - this was a massive task"* (SM.1).

Given the scale and complexity of the task, decisions related to supplier selection were surprisingly rapid. Conversations between the buyers and suppliers were focussed on availability and capacity rather than cost. Orders were committed within days, with the buyers empowered to make rapid selection decisions, in contrast to the normal Rolls Royce procurement process, placing trust in the integrity of their global networks. This was supported by PA Consulting undertaking the necessary due diligence with respect to certification and accreditation: "*we were still able to follow the right quality guidelines because we had that step in place as part of the programme management group"* (RR.3).

In total, the buyers sourced 121 new suppliers, the majority of which were not accredited for medical grade ventilators. Activities that would normally take Rolls Royce three to four years of programmes with suppliers to complete, took five to six weeks of laser focus by five dedicated quality and manufacturing personnel who "*just flogged through the accreditation process*" (RR.2).

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Although the ventilator design was tried and tested, "*they would normally be distributed in the tens, not the thousands. This was an order of magnitude and very different than normal*" (RR.1). From the start Rolls Royce established the capacity and production line speed of every new supplier and *"completely re-organised the team not to think about strategic sourcing, but demand management…its' all geared up towards time and capacity, not price and contract*" (RR.1). This was a complete shift in the way of doing business necessitated by the project.

The second strategy pursued by the *Ventilator Challenge* consortium - to design and build completely new ventilators – was launched in parallel with the project to ramp up production of the Parapac 300. This meant that the two groups were looking for the same suppliers to source parts, which created bottlenecks. At a programme level, this was managed by PA, who prioritised available parts dynamically across design teams. Locally, Rolls Royce dealt with this by ensuring that they knew the production capacity and complexity of each component from every supplier. Suppliers were not left to sort out any problems by themselves and where necessary, Rolls Royce sought alternative suppliers: "*because of the nature of this project we were super agile in being able to react when needed to make a change*" (RR.4).

There are only one or two companies in the world that make some of the key component parts required in ventilators. Given the high demand, the most senior Rolls Royce buyers were assigned to these parts and immediately focused on building close relationships as quickly as possible and providing upfront payments to guarantee supply. Nevertheless, the task of ramping up production to the required level was bound to create bottlenecks, particularly for complex parts for which there was simply insufficient capacity from existing suppliers *"I don't think anyone realised how quickly we'd move and our ability to secure certain critical path items with the timeframe was challenging"* (RR.4).

This was a challenge that the consortium was uniquely positioned to tackle, with world class engineering expertise from aerospace and Formula 1, what could not be sourced was made, using spare capacity resulting from the lockdown. For example, something like the gears "*it would be quite easy for us to take something like that and say right we know that you can't produce this, but in this emergency, give me your design and I'll get them made by somebody*" (RR.1). This could only be accomplished through mutual trust and a universal appreciation that what individuals and organisations were being asked to do was essential if lives were to be saved *"Everyone really wanted to help save lives. I have never seen anything like it. Rolls*

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Royce, GKN, Williams, McLaren. There was no profit involved, but there was an enormous amount of people's time and energy" (SM.1). Rolls Royce also had a 'fast-make' team in place for their existing business, with a network of precision machining suppliers with the capacity to "*do really quick, short lead time, difficult to engineer tasks*" (RR.4).

Test boxes were used at every stage of production to manage quality. This was essential for regularity approval and each stage of assembly and sub-assembly is subject to specific tests and protocols. There were only 13 test boxes available when the project started but the targeted increase in production in such a short period of time meant they would need 150. These were extremely complex devices comprising components, such as bellows and flow metres, that would be impossible to source in the time available. A further complication was that, as with the Parapac 300, Smith's designs for the test boxes were old, meaning they had to be completely reverse engineered by the teams at McLaren and Williams. "*That was massive task for them - the feat of engineering was phenomenal, they reversed engineered everything, sourced it and produced it. Then on top of that you have to train people to use the test boxes"* (SM.2).

Within three weeks components were being shipped to the high-quality manufacturing and assembly lines set up by GKN and Rolls Royce. The level of intensity and tolerance for the assembly of ventilators is very fine, with thirty sub assembly stages requiring individual tests. From the assembly perspective this was a huge task for Smiths Medical as all the training was undertaken remotely using virtual reality. *"We filmed the production line in Smiths Medical and turned that into a VR training package. People were at home with these goggles and going through the manufacturing process. We had them do test assemblies and video them so that people could look at them. The use of technology was a boom in terms of maintaining the pace in a remote environment"* (SM.2). The engineers at GKN and Rolls Royce created lean production lines to maximise the line flow without compromising safety or quality.

In an agile supply chain it is impossible to stabilise all variables at the outset. One key example was production capacity, unknown until the first end-to-end production cycle had been completed. A second example was material requirements demand, which would inherit volatility from the variable production capacity assumptions. The response to such uncertainties was, somewhat paradoxically, to impose structure onto flexibility. *"This was achieved by scenario modelling into the supply chain to support rapidly changing underlying assumptions. In parallel, a formal mechanism for sending ad-hoc material shipments when*

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initial planning estimates undershoot was put in place and supported by the E2Open supply planning solution" (RR.7).

3.3 Technology

To facilitate supply chain visibility and the challenges of integrating a number of bespoke information, operations management and accounting systems, Rolls Royce chose to outsource the entire supplier management and payment process to Accenture. In turn Accenture built a 'simple' ERP system that was more than adequate for the purpose of the project, without the multi-functionality that would be found in advanced ERP systems, but which would have taken much longer to adapt and integrate within the consortium. The information, data management and visualisation system that Accenture put together, with support from Avenade, E2Open and Microsoft (Power BI) is illustrated in Figure 3. It enabled them to *"get the POs to suppliers, track their shipments and figure out where all the materials were, which was a logistical nightmare"* (A.2).

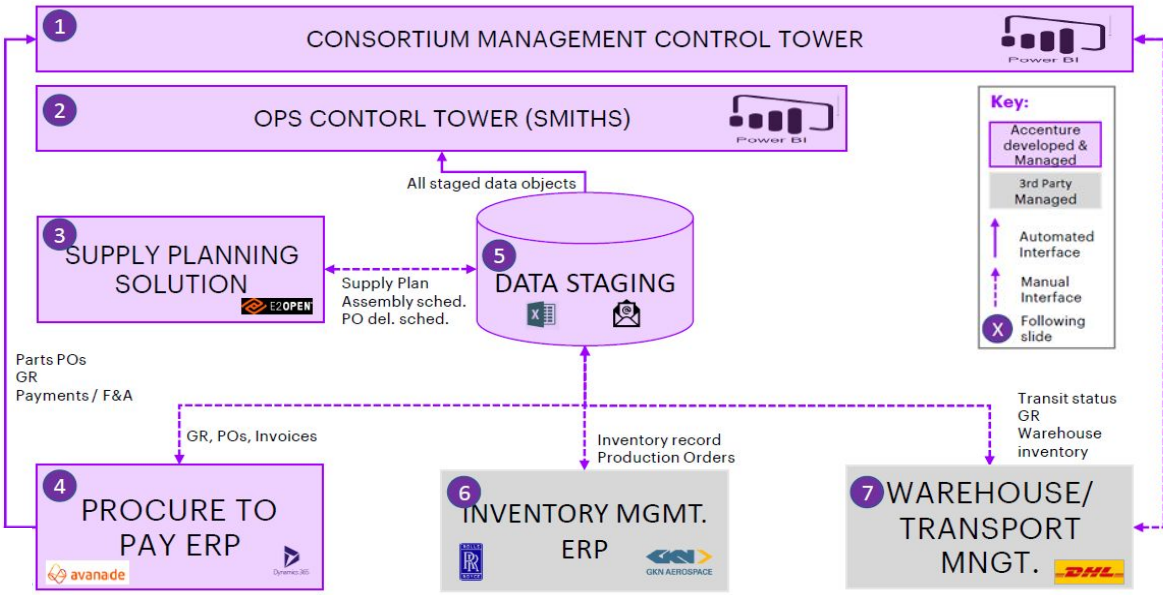

Figure 3 – Information and Data Management System

Accenture was a natural fit for the consortium as they had developed their digital manufacturing practice with many UK manufacturing companies. They offered expertise in procurement transformation and had close relationships with Rolls Royce and other industry leaders. Accenture dedicated fifty people to the project team. The team worked as fast as

possible to order parts and expedite shipments, while at the same time ensuring everything was completed quickly, maintaining efficient practices and timely payments to suppliers "*We needed to track shipments, figure out where all the material was and supplier them paid. So we brought three types of skills, people who think about process, people who design and technical people who can operate the process and the system*" (A.2).

In order to manage the huge numbers of parts, Accenture worked with Avanade, their joint venture with Microsoft, to deploy and support an Enterprise Resource Planning (ERP) system, that integrated supply operations and purchasing functions (See Figure 3). The automated system brought efficiencies and along with the supply chain Control Tower, enabled by PowerBI and E2Open software to provide co-ordination, oversight and governance across the process from start to finish.

Inspection of components prior to shipment was kept to a minimum, as the consortium had to balance orchestrating 100 new suppliers and millions of parts while doing everything at breakneck speed. This was an agile boundary-less ecosystem operating for a shared purpose and the common good.

The Control Tower supported the monitoring and management of the process end-to-end, providing visibility to all consortium members through digital dashboards showing the status and real-time metrics of the parts sourced, in transit and in assembly. No software licensing had to be paid and the Cloud based technology was implemented very quickly. To get the supply chain up and running, speed was essential and processes were designed for simplicity to manage the complicated bill of materials of 3.5millon parts. "*We were not trying to go wall to wall with any single solution. The approach to take the right fit solutions according to the process we were enabling. We had a number of solutions knitted together in an agile way to support the value changing from sourcing through to assembly*" (RR.7).

Twice daily reporting meetings took place with the Cabinet Office, DHSC and consortium members to ensure data was correct and resources deployed with precision where needed. "*We benefited from a very flat governance structure, with only 2 layers – one reporting line that Rolls Royce had into the Cabinet Office and then a reporting line that the consortium had into Rolls Royce*" (RR.7).

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Accenture organised the entire "procure-to-pay" procedures and set up a customised ERP system, to align the 'push' created by procurement with the 'pull' from the four production lines. The control tower created by Avenade provided end–to-end supply chain visibility, which was essential given the variation in demand across the four production sites and the variation in supplies arriving into DHL, many of which were small consignments of tiny components which had to be broken down prior to shipment onto the production line. Again, this differs considerably to the consignments of large modular units DHL were accustomed to handling for the automotive sector.

Managing data to ensure visibility in a brand new supply chain is extremely complicated. During the *Ventilator Challenge* this was an ongoing process. Due to the nature of the project, processes were new and sometimes untested, which meant that efforts to monitor and continually evaluate their effectiveness were maximised. "*The control tower, which is the data and the visualisation of the data would show an early indication of bottlenecks*" (A.2). The consortium invested continual effort to track three tiers of activity: shipment activity from suppliers, parts warehouse inventory and material consumption rates at the assembly locations. This generated a vast quantity of data from disparate sources and an important activity was to corroborate and match "flow" data from third-party logistics providers and "stock" data at each of the supply chain nodes. For example, "*if the logistics provider reported delivery of 500 widgets, yet an assembly location reported receipt of 5,000 widgets, then it is likely that data sources are using different units of measurement; the assembly location reporting the number of widgets, whilst the logistics provider counting in packs of 10 widgets*" (RR.7) Such discrepancies needed to be monitored carefully.

Data visibility and visualisation was critical and an operational management dashboard built by PowerBI visualised progress and performance at each node of the new supply chain. Deploying this kind of "rapid BI" allowed for monitoring operations in-house as well as reporting and communication to external stakeholders. Data visualisation helped to expose data errors. "*It was essential to factor in sufficient resources to iterate and evolve the visualisation capability and in conjunction with evolving supply chain data it was easier to identify and suppress teething issues as the new supply chain developed*" (RR.7).

A key learning from the project was the need to make tactical trade-offs to gain and maintain velocity. Supply chain planners typically focus on the task of refining and customising operating processes moulded to well-defined business requirements. In an agile supply chain,

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some of these "luxuries" must be tactically sacrificed, with eyes wide open, in return for shorter set-up times and fulfilment cycles. From a system perspective, attempting to create a bespoke ERP system would have create unacceptable delays. In its place, Accenture deployed an "Off the shelf" solution implemented by Microsoft Dynamics 365, which provided powerful ERP functionality immediately without the need for lengthy set-up time to customise the solution. Also, the cloud-based control tower supported efficient real-time collaboration within the team despite the "working from home" protocols necessitated by COVID-19. This enabled a rapid and co-ordinated responses to problems that were visible to all, despite remote working, and challenged organisational orthodoxies, such as the commonly held belief across Aerospace and Defence that they could not utilise the Cloud without compromising security.

3.4 Environment and Culture

Commitment at the highest level by the most senior personnel provided essential and inspirational leadership from the outset "*it must start with the senior people articulating the sentiment…then nothing can stop us from making this happen, keep going and look for a solution*" (R.3). This ignited the consortium members, "*it was behavioural, giving people the empowerment and the positive leadership to just go and make it happen*" (RR.3).

Speed was of the essence and the message to the volunteers on March 26th was *"we've got to put a duplicate supply-chain in, we've got to do this as quickly as possible and we've got to make as many ventilators as possible"* (RR.2). Leadership came from a small group of senior managers, with the sourcing and procurement effort led by an executive with over forty years' experience with Rolls Royce: *"I guess by default and through my experiences, I started to lead the supply chain element, analyse and absorb. That is what I am trained to do, analytics"* (RR.2). Within 24 hours the team started to put the governance framework together. Essential to this was to set the working context so as to build a no-blame culture within the team "*we are all going to work together, we are going to make mistakes, but we'll learn from them, if something goes wrong we'll use good knowledge management and learn from it*" (RR.2). This turbo-charged the team with a liberating mind-set, whilst the strap-line "*we're saving lives*" galvanised individuals to operate at speed and with agility, trusting their instincts *"there was a lot of young people and a lot of people with experience and I think that was useful as well. So, you've got people like me, who's been there 20 years with lots of contacts and network and then you've got people like xxx who, you know, was really thinking outside the box about the way in which to get hold of people"* (RR.5). It also made it easier for senior managers to ignite

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a workforce that only 3 days before the consortium was launched had found themselves furloughed due to the nationwide lockdown *"A clear sense of purpose was tangible – we are not picking parts for ventilators we are picking parks to save lives. Being able to articulate that to the team on site made things easier, without a doubt"* (DHL.1). Further support and reassurance derived from the sharing of challenges encountered and lessons learned via daily team meetings. *"This was really about a positive culture with purpose led objectives, this culture accelerated collaboration"* (RR.7).

There appeared to be a resetting or recalibration of culture and behaviours, everyone was "*facing a common enemy- COVID-19*" (RR.1). The ventilator project was very challenging, "*I remember working 12 hour days and over weekends, so was absolutely mentally exhausted…. You really felt as like you were contributing to something*" (RR.6). There was a common goal and objective shared by everyone, a 'national spirit', where all parties in the consortium set aside corporate identities and acted as individuals with a particular role and set of expertise to provide a solution for the common good. "*This was a wartime effort. We weren't thinking about IP or anything like that at the time, we were thinking about how we could save lives. Every individual on the team has worked night and day, gladly, freely and willingly and have been proud to be part of it … it is almost a sense of wartime unity, is the only way to describe it*" (RR.3). As one respondent put it "*the power of purpose was the biggest thing. Having a common goal, it worked miracles. This is what enabled us to do what would normally have taken 18 months in 8 weeks*" (A.1).

Even at the accelerated pace of the project, quality and safety was not compromised, "*we have not overlooked anything, quality or regulation, we just did it faster*" (RR.3). Buyers worked on the basis of their experience and expertise with little governance, they knew what they had to do, trusted their judgement and were empowered to act without recourse to the regular bureaucratic processes ingrained within the organisation. Rolls Royce have very mature sourcing strategies and bureaucratic procurement processes, which were largely redundant for this project. Rather, buyers went back to basics "*you're the Buyer and you're a procurement person, find a great supply chain, get the right price at the right quality and then send an email to Accenture and they'll do the rest*" (RR.3). Weekly reporting to the leadership team was about solving problems and supporting the buyers so that they did not run into any issues. This created a great deal of commitment generated a huge amount of self-worth, satisfaction and esprit-de-corps for all those involved.

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4. Linking the case study to literature

As discussed, the opportunistic nature of data collection invites a retrospective review of literature. The four key themes identified in the case study are explored in literature: context, sourcing and procurement, technology and culture and environment. By linking empirical insights to literature, support for existing research is offered and new insights for resilience and agility highlighted.

4.1 Context

It is clear from the case study that operations in the *Ventilator Challenge* and wider COVID-19 pandemic were unprecedented. COVID-19 called for a response unlike that of typical or best practice procurement discussed in the existing literature. Of particular significance is the establishment of the Common Good, which contributed to a collective belief and determination and welcomed volunteers. The case study demonstrates the success of this, contradicting the widely accepted claims that crisis prohibits procurement, resulting in diminished capacities (Schultz & Søreide, 2008; Atkinson & Sapat, 2012; He *et al.,* 2016). Rather, as discussed in the following sub-sections, COVID-19 appears to have elicited advanced agility from Rolls Royce and other consortium members with particular reference to sourcing and procurement, technology and culture and environment. In offering rich new insights relating to procurement at an accelerated pace, this reinforces COVID-19 as a novel and invaluable context to develop supply chain research (Ivanov & Dolgui, 2020; van Hoek, 2020).

4.2 Sourcing & Procurement

As a key strategic activity (Chibani *et al.,* 2018) at the forefront of supply chain management (Devaraj *et al.,* 2012), procurement is a time consuming activity reliant on rigorous planning, management and assessment (Rane *et al.,* 2019). This differs to the depiction of procurement in the case study where Rolls Royce developed an entirely new, parallel supply chain in extremely limited time. To some extent, the capacity to do so may be attributed to agile procurement, which offers a more flexible and responsive approach (Chibani et al., 2018). That is, via agile frameworks, techniques and technologies (Ng & Navaretnam, 2019), the supply chain is able to respond quickly to sudden changes (Aitken et al., 2002). However, this again differs to the case study, as whilst agility may be embedded at Rolls Royce it had to be established in the new parallel chain. Establishing agility is again time consuming, requiring complex design of operations and networks (Al-Shboul, 2017). There was no time for this in the *Ventilator Challenge*. Rather, as Pettit *et al.,* (2019, p56) suggest, crisis necessitates

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"exceptional agility to cope with unexpected shocks". The case study offers some explanation to the realisation of such exceptional agility.

Supplier selection in the *Ventilator Challenge* prioritised speed over any other selection criteria. This differs to existing procurement research that prioritises cost, quality and time (De Araújo *et al.,* 2017) and agile research that prioritises agility and capacity to meet demand and service expectations (Al-Shboul, 2017). Rather, the case study aligns with claims that in crisis the crisis itself is prioritised (De Araújo *et al.,* 2017): all that mattered was saving lives and cost was not considered at all. As a result, optimal selection processes were replaced with quicker informal recruitment via internal social media and volunteers. This conflicts existing literature's emphasis on multi-criteria decision-making (Chai & Ngai, 2015), expert segmentation (Santos et al., 2017) and rigorous contracting and planning (Rane *et al.,* 2019) in recruitment and selection. Whilst it is argued that forgoing such checks and assessments risks increased unpredictability or unreliability (Atkinson & Sapat, 2012; He *et al.,* 2016), the case study demonstrates advanced rather than prohibited agility.

4.3 Technology

As the case study demonstrated, accelerated supplier selection and recruitment was made possible via implementation of ERP systems. This aligns with existing literature, which supports the use of technological support systems in agile procurement (Chase, 2016; Pettit *et al.,* 2019). In fact such is the significance of ERP in supporting agility that it has evolved into 'Agile ERP', offering *"reduction of time-to-market for new products, improvement in product quality and predictable as well as sustainable innovation of products and business processes"* (Misra *et al.,* 2016, p41). Out with typical market demand instability, more recent literature recognises the value of ERP in mitigating unpredictable demand, infrastructure breakdown and resource unavailability in times of disruption (Falagara Sigala *et al.,* 2020).

Such literature highlights the complexity and critical importance of the development, implementation and control of ERP (Misra *et al.,* 2016). Typically reliant on pre-established systems, ERP adoption during disruption is considered problematic (Falagara Sigala *et al.,* 2020). However, the case study evidences successful implementation of ERP at speed and reinforces the value of ERP in advancing operations in unprecedented disruption. Importantly, findings suggest successful implementation does benefit from exploring tried and tested tools such as Excel prior to the development of bespoke software. This affords ad-hoc or manual

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system interventions in response to limitations regarding data accuracy and availability, demand history and supply chain planning.

4.4 Culture and Environment

As demonstrated throughout the case study, the Common Good has cultural and environmental influences that contributed to its success. The desire to help and contribute to the common good drove people to trust their instincts and work swiftly in ways that would normally be prohibited by established operating protocols. This suggests that it is not so much the existence of established processes that is critical for agility in procurement emphasised in the literature (Aitken *et al.,* 2002), but rather the existence of outstanding people. Therefore, the case study aligns with literature that emphasises the 'human-centric' nature of operations (Scholten, *et al.,* 2019), particularly in times of disruption. That is, the need for employees with an agile mind-set (Rane *et al.,* 2019) to understand and respond to change (Pettit et al., 2019) is brought to the fore. In the *Ventilator Challenge*, this translated to highly skilled and self-confident people, but importantly who were capable of adapting and prioritising the team ethos over the individual ego for the common good. Volunteers highlighted skills relevant to the need to operate at speed which they were neither accustomed nor comfortable. As the challenge was unprecedented, capacity for previous experience was limited, undermining the emphasis on past behaviours and experiences in literature (Vanpoucke & Ellis, 2019).

The unprecedented circumstances of the *Ventilator Challenge* also limited capacity for collaboration with existing, trusted partners. According to Vanpoucke & Ellis (2019, p14) "*closer buyer–supplier relationships create additional mechanisms for sensing what is happening at the supplier"* and therefore supports quicker decision making, responsiveness (Ng & Navaretnam, 2019) and agility (De Araújo *et al.,* 2017). However, the parallel supply chain was established without recourse to existing suppliers to Smiths Medical for all but a handful of critical components for which there were no alternative sources. Existing literature suggests this is typical of an emergency response, where relief efforts and shortages often call for new suppliers to fulfil unexpected needs (Vanpoucke & Ellis, 2019). Such diversification lacks the benefits of established relationships (He *et al,* 2016). Literature warns this can be particularly problematic with regards to communication and visibility, whilst rapid acquisition and inefficiencies can cause difficulties with payments and financial control (Schultz & Søreide, 2008; Atkinson & Sapat, 2012). This can make it difficult to satisfy demand, which remains the core function of procurement (Shi *et al.,* 2011). There is clear evidence of this in

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the case study, where the lack of a common language, data visibility and visualisation emerged as significant challenges, delaying the start and inhibiting the pace of ventilator production, in the first few weeks. The solution to this challenge was found in the information systems and the integration thereof. Interestingly, this was itself the product of collaboration. More specifically, Accenture worked with Avenade and Microsoft to integrate the custom ERP system with the P2P system and the control tower. This provided enhanced visibility across a supply chain comprising 75 brand new suppliers with no prior experience in the production of components for ventilators and no trading history with Rolls Royce.

5. Conclusions

This case study responds offers empirical explanation of supply chain capacities within the novel context of COVID-19, which deliver contributions to literature and practice. This presents a new perspective of agile procurement and supply chain management in times of crisis for academics and practitioners. Limitations and areas for future research are also discussed.

5.1 Contributions to Literature

As demonstrated in section 5, this makes a number of contributions to literature. By exploring the supply chain in the novel context of COVID-19 rich insights are offered, with particular reference to context, sourcing and procurement, technology and culture and environment. Predominantly, the case study provides deep insight into how the consortium was able to build an entirely new ventilator supply chain within five weeks – as the unprecedented context demanded. This contributes to efforts to advance resilience approaches (Pettit et al., 2019) beyond survival (Ivanov, 2017; Scholten, et al., 2019), to explain how the supply chain adapts at an accelerated rate for recovery.

Specifically, whilst the significant role of sourcing and procurement in any organisation is well-documented (Pettit *et al.,* 2019), the case study explains how it can be accelerated successfully. To meet unprecedented demand for medical ventilators prioritised supplier selection and created agility in practices and processes that were in normal circumstances often lengthy and sometimes cumbersome. Typical selection criteria and recruitment adapted: buyers were empowered to seek out new suppliers who had availability and capacity to produce the required ventilator parts. This acknowledges He *et al's* (2020) findings that in times of crisis employing a mitigation strategy involves sourcing new suppliers to fulfil unexpected needs. Literature

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emphasis on risk due to speed of selection, incomplete checks and balances during the supplier selection processes (Schultz & Søreide, 2008., He *et al.,* 2016) are contested by the success of the *Ventilator Challenge*. Risk assessment practices and procedures were rigorous despite the unpredictable and uncertain environment. Quality was never compromised and procedures were in place to rapidly accredit suppliers and bring them up to the required ISO standard. Cost, usually a critical factor in sourcing negotiations, was not considered. The role of government oversight and support in relation to the mitigation of financial risks is important here.

The role of technology in providing essential supply chain visibility and facilitating multi-stakeholder engagement is brought to the fore. Moreover, this contributes to existing discussions surrounding the critical need to facilitate communications (Chibani *et al*., 2018) and collaboration (De Araújo et al., 2007) in response to sudden change. The ERP system operated and managed by Accenture integrated the supply operations with Rolls Royce purchasing functions and the control tower ensured end-to-end supply chain visibility. An off-the-shelf ERP system employed during the programme, designed to manage complicated and large bill of materials, provided exceptional agility. The important role of digital technology via the control tower ensured complete visibility of real-time data to all members of the consortium. The use the technology brings into question accepted orthodoxy that Cloud based technologies are insecure.

Finally, rich insights relating to cultural and environmental influences in procurement are offered. In particular, the consortium's use of crowdsourcing approaches to access internal organisation and personal networks is interesting and unusual given the high security nature of the organisations involved. This contributes to a growing support for crowdsourcing in times of disruption where speed and responsiveness is imperative (Xu *et al.,* 2016; Wang *et al*., 2019; *Paik et al.,* 2020). The significance of individual and collective skills is also emphasised in the findings. The power of purpose energised individuals to overcome organisational constraints and behavioural norms in pursuit of the common goal. The collective skills of consortium members were essential in delivering ventilators at speed and raise interesting findings relating to collaboration. To some extent, the significant role of collaboration and trust in agility is supported: the rapid development and integration of ERP was a product of collaboration between existing partners Rolls Royce and Accenture; whilst delayed production resulted from a lack of common language, data visibility and visualisation with new partners. However, the

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overall success of the *Ventilator Challenge* demonstrates capacity to operate at extreme speed in unprecedented circumstances in an entirely new supply chain.

5.2 Contributions for Practice

This case study describes an overwhelmingly positive reaction by individuals and exemplifies what can be achieved when people unite to address a common cause. Organisations stepped up to the mark and individuals worked round the clock for weeks, managed pinch points and dealt with anxieties as the project got off the ground and progressed. This was an unprecedented situation and although it may be too early to fully identify how the experience of being involved in the *Ventilator Challenge* might alter attitudes and working practices, there are clearly some early lessons to be learned for practitioners. "*Let's not throw the baby out with the bathwater…. Let's make sure that we capture the things that have worked for us and would provide positive benefit and allowed us to do things more expeditiously*" (RR.1).

In anticipation of an increase in the frequency of disruptive events in coming years (He *et al.,* 2016; Kaur & Singh, 2019), the critical role of sourcing and procurement should be prioritised. This study highlights the need and capacity for an entirely new supply base to fulfil unexpected needs. Supplier selection must be able to evolve to prioritise the needs of the crisis – as demonstrated in the case where there exist *"very few companies all over the world that possess the expertise to manufacture ventilators"* (Iyengar *et al.,* 2020, p500). The complexity of this is exacerbated by significant time restriction and global supply network and daily operation disruption. Importantly, in spite of associations of increased risk and unpredictability (He *et al.,* 2016), approaches adopted by the consortium evidence that such adaption is possible and may result in advanced procurement.

Advanced procurement is supported by information technology. For example, in managing payments, practices and supplier expectations and order fulfilment Accenture's ERP system supported fast, efficient and automated procurement, adding support for continued investment in such systems (Falagara Sigala *et al.,* 2020). Alongside ERP, the value of social media in procurement is brought to the fore, consistent with its increasing application in practice (Costa & Tavares, 2014; Xu *et al.,* 2016). Internal social media channels, a group WhatsApp and employees' own social networks expedited the search for and collaboration with suppliers. This aligns with the presentation of social media as a virtual community in which companies share information, collaborate, plan and execute projects (Gao *et al.,* 2011). The advanced

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communication, immediacy of information and decision-making facilitated by social media (Habibi *et al.,* 2015) responded to the need for rapid production of ventilators in COVID-19 (van Hoek & Lacity, 2020). Thus, the case supports the application of social media in advancing procurement in times of disruption (Simula *et al.,* 2013; Xu *et al.,* 2016).

Considering cultural and environmental influences, the significant role of individual managers and employees is recognised. Empowered and skilled buyers were essential in the *Ventilator Challenge.* Supplier quality, capacity and capabilities were tried and tested using established Rolls Royce quality checks and undertaken by experienced buyers. Building resilience to mitigate future shocks means that upskilling and training will be critical to the nation's recovery. Investing in work-based learning and developing a workforce's in-demand skills could be a source of competitive advantage. Government and Industry will have to "*look at the way people work, looking into the future, upskilling and learning and using the workforce in a completely different way. This is more far reaching than thinking about systems and processes, it is "a more fundamental shift of how businesses function and operate*" (RR.1).

Additionally, trusted partners and collaboration played a critical role and should also be prioritised. Smith Medical's approved and tested ventilator design was used, corresponding with Iyengar et al.'s (2020) call for open-source design and sacrifice of intellectual property in the production of COVID-19 ventilators. The governance structure established at the outset, combined with the TDA, comprising representation from the users (NHS), the regulatory body (MHRA) and the programme manager (PA Consulting) ensured that neither safety nor quality were compromised. This is particularly important given that limited time and experience in a pandemic suggests that the maintenance of quality and regulatory compliance become problematic to manage (Ivanov & Dolgui, 2020) and thus potentially compromised (Vlček, 2018).

Importantly, all the capacities discussed above demonstrate optimisation of speed, flexibility and responsiveness and thus support the adoption of an agile approach (Chibani *et al.,* 2018). Reinforcing this, agility's reliance on collaborative relationships (Vanpoucke & Ellis, 2019), employee skills (Aitken *et al.,* 2002), an agile mind-set (Rane *et al.,* 2019) and ERP (Misra *et al.,* 2016; Pettit *et al.,* 2019) are all clearly implicated throughout the case. However, the agile approach adopted expands beyond that aimed at responsiveness to existing markets (Chibani *et al.,* 2018). Rather, the need for complex resources (Iyengar *et al.,* 2020; van Hoek & Lacity,

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2020) and complete modification of operations (Ivanov & Dolgui, 2020) in new or unknown markets (van Hoek & Lacity, 2020) amidst unprecedented global disruption and restrictions (Baveja *et al.,* 2020) called for advanced agility. Thus, the impressive response by consortium members advocates the adoption of an expanded agile approach.

5.3 Limitations

There are several methodological limitations resulting from the unprecedented context of COVID-19, which impacted the collection and analysis of data. First, the. As discussed, time and access constraints were exacerbated, meaning that no interviews were conducted with three (GKN, McLaren and Williams) of the eight key members from the consortium involved in the case study. Whilst this does limit representivity, this is mitigated by the focus on agile sourcing and procurement, which is well represented in the data. Second, not only were all interviews conducted online, but all the discussions and the analysis of the transcripts were undertaken remotely, adding to the complexity of the task and the time required. The capacity to deal with this as a research team improved markedly over the eight months in which the study was undertaken. Third, the novelty of COVID-19 and the *Ventilator Challenge* could have resulted in gaps in understanding or interpretation of events. Circulation of drafts of the case study to involved stakeholders sought to address this. Finally, the qualitative inductive approach and manual thematic analysis may have had a negative impact on methodological rigour. However, this is mitigated by intercoder reliability, the experience of the research team and 'ground-truthing' of the case findings with the stakeholders involved.

5.4 Recommendations for further research

The case study highlights behavioural factors that underpinned the success of the *Ventilator Challenge*, with particular reference to the Parapac programme. Individuals rose to the challenge and put aside personal and organisational agendas to act as one for the "common good" in a time of severe national crisis. It is apparent that leadership affects how individuals and teams operate. An overwhelming factor in the success of the *Ventilator Challenge* was the sense of empowerment, which altered mind-sets and emboldened people to trust their instincts and leverage the power afforded consortium members, as respected leaders in their respective sectors. This contribution opens the door for procurement research to explore more closely how behavioural aspects of procurement management are embedded in procurement practice and training.

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Whilst agile procurement is an important part of the success story that is the *Ventilator Challenge*, agility in other elements of supply chain management – design, manufacturing and logistics - were of equal, if not greater importance, and warrant consideration for further researchers. The passage of time may make it more difficult to capture detailed insights of who did what but may facilitate more reflective consideration of the lessons learned for theory, method and practice.

The *Ventilator Challenge* as a whole delivered end-product from other vendors beyond Smiths Medical, as well as approval-ready novel systems and IP. Fifteen design and supply programmes ran in parallel to ensure there were ventilators of diverse clinical utility available suited to all eventualities. Each of these programmes has its own story to tell, and together there may be further insights of value to consider beyond the scope of this case study research.

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Table 1

Consortium	Respondent	Position
Rolls Royce	R.1	Chief Procurement Officer
Rolls Royce	R.2	Supply Chain Operations Supplier Executive
Rolls Royce	R.3	Head of Procurement Excellence, Civil Aerospace
Rolls Royce	R.4	Buyer – Raw Materials
Rolls Royce	R.5	Supplier Relationship Manager
Rolls Royce	R.6	Strategic Buyer
Rolls Royce	R.7	Digital Manufacturing Director
Accenture	R.8	Managing Director - Aerospace and Defence
Accenture	R.9	Senior Manager-Supply Chain Operations
Smiths	R.10	CFO Medical Division
Smiths	R.11	Head of Operations
DHL	R.12	Vice President Automotive (Tier 1 & Niche)
PA Consulting	R.13.	Technical Consultant
PA Consulting	R.14	Senior Partner

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Table 2 Emergent Themes & Data Coding

Theme	Codes	
	Challenges	**Enablers**
Context	• Covid-19: national emergency • Speed: urgency, rapid change, responsiveness	• Purpose: collective belief, determination, common good, wartime effort • Serendipity: spare capacity, volunteers
Sourcing and procurement	• Safety: compliance with MHRA standards • Uncertainty: production capacity, bottlenecks • Complexity: specialist components • Risk management: Intellectual Property, Quality Assurance • Supplier selection: evaluation, recruitment	• Governance: project management • Collaboration: trust, respect • Agility • Flexibility • Functional expertise and experience
Technology	• Visibility: data capture, analysis and sharing	• ERP • Control Tower • Communication: continuous, open multi-channel, social media
Culture and Environment		• People: mindset, motivation • Leadership: authority, teamwork, empowerment, • Collaborative relationships

Figure 1

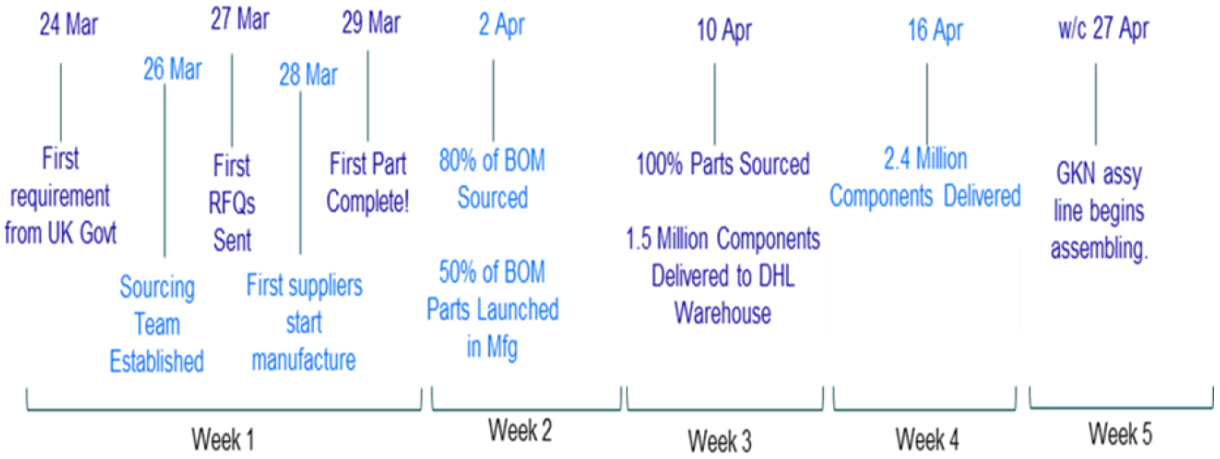

24 Mar
First requirement from UK Govt
26 Mar
Sourcing Team Established
27 Mar
First RFQs Sent
28 Mar
First suppliers start manufacture
29 Mar
First Part Complete!
2 Apr
80% of BOM Sourced
50% of BOM Parts Launched in Mfg
10 Apr
100% Parts Sourced
1.5 Million Components Delivered to DHL Warehouse
16 Apr
2.4 Million Components Delivered
w/c 27 Apr
GKN assy line begins assembling.
Week 1
Week 2
Week 3
Week 4
Week 5

Figure 2

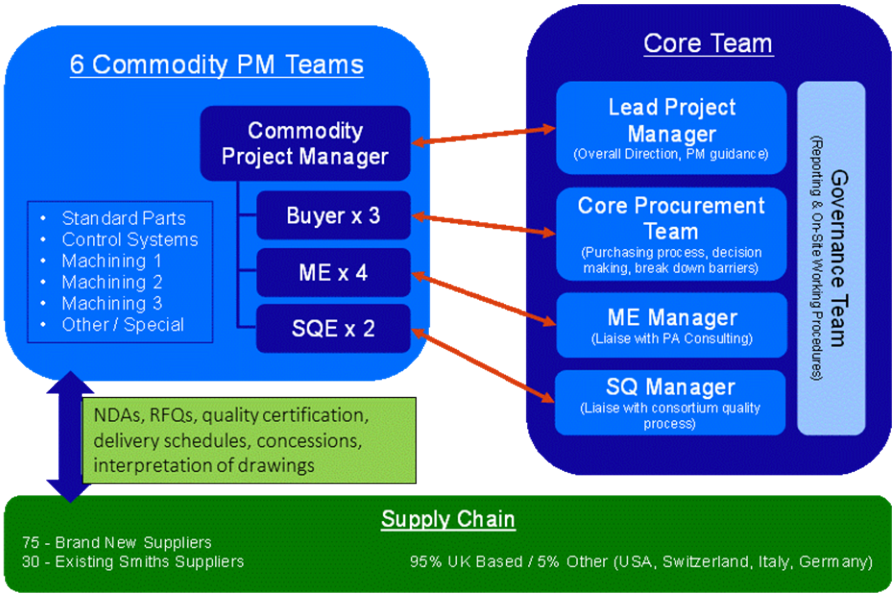
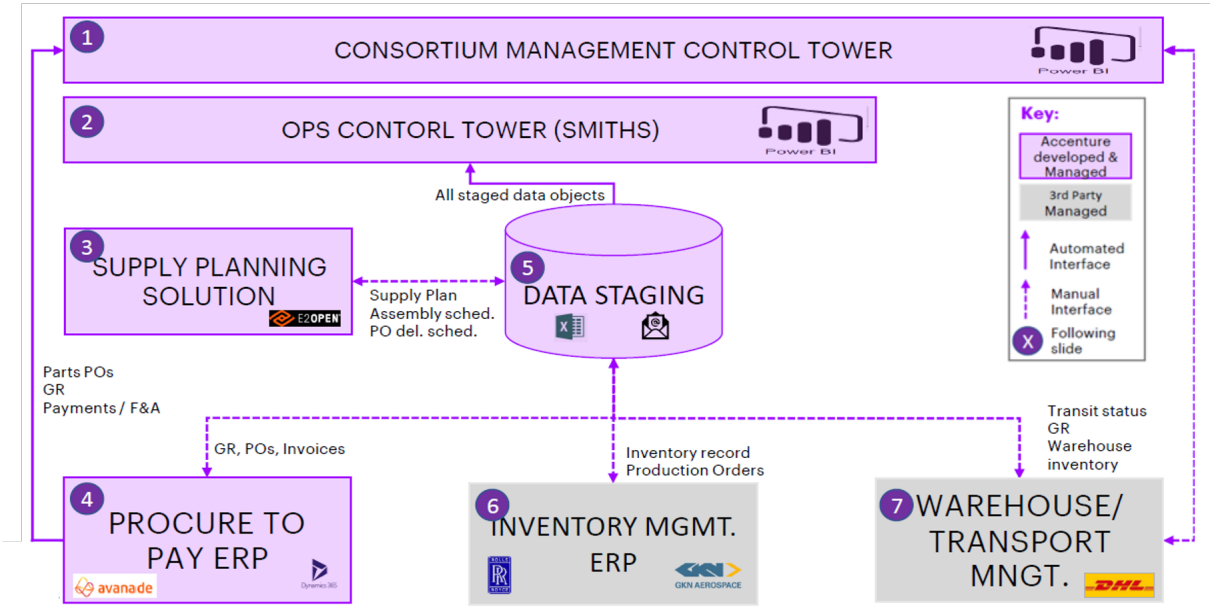

6 Commodity PM Teams
Commodity Project Manager
Buyer x 3
ME x 4
SQE x 2
Standard Parts
Control Systems
Machining 1
Machining 2
Machining 3
Other / Special
Core Team
Lead Project Manager
(Overall Direction, PM guidance)
Core Procurement Team
(Purchasing process, decision making, break down barriers)
ME Manager
(Liaise with PA Consulting)
SQ Manager
(Liaise with consortium quality process)
Governance Team
(Reporting & On-Site Working Procedures)
NDAs, RFQs, quality certification, delivery schedules, concessions, interpretation of drawings
Supply Chain
75 - Brand New Suppliers
30 - Existing Smiths Suppliers
95% UK Based / 5% Other (USA, Switzerland, Italy, Germany)

Figure 3


1
CONSORTIUM MANAGEMENT CONTROL TOWER
Power BI
2
OPS CONTORL TOWER (SMITHS)
Power BI
All staged data objects
3
SUPPLY PLANNING SOLUTION
E2OPEN
Supply Plan
Assembly sched.
PO del. sched.
5
DATA STAGING
Key:
Accenture developed & Managed
3rd Party Managed
Automated Interface
Manual Interface
X Following slide
Parts POs
GR
Payments / F&A
GR, POs, Invoices
Inventory record
Production Orders
Transit status
GR
Warehouse inventory
4
PROCURE TO PAY ERP
avanade
6
INVENTORY MGMT. ERP
GKN AEROSPACE
7
WAREHOUSE/ TRANSPORT MNGT.
DHL