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Empirical Research Paper

Operation Warp Speed: Projects responding to the COVID-19 pandemic

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ABSTRACT

The 2020 COVID-19 pandemic has profound socio-economic consequences. Extraordinary times call for extraordinary measures, so this paper focuses on radical changes to accepted practice in project organizing in response. In particular, we focus on schedule compression to deliver outputs to mitigate the immediate impact of the pandemic on health. In the spirit of engaged scholarship, which is problem-driven rather than theory-driven, we address directly the evidence of what happened in two empirical vignettes and one more substantial case study – the CoronavirusUY app; emergency field hospitals; and vaccine development. We then suggest the implications for project management theory in discussion.

1. Introduction

The COVID-19 pandemic that swept the world during 2020 has had profound social and economic consequences that will have a long-term effect on economy and society (British Academy, 2021). It is by far the most serious crisis to hit the global economy since 1945, and the worst global pandemic since 1918. Extraordinary times call for extraordinary responses, and this paper will focus on radical changes to accepted practice in project organizing in response to the crisis. In particular, we focus on schedule compression to deliver outputs to governments to mitigate the immediate impact of the pandemic on health, and, in the slightly longer term, provide a route map to the "new normal" of post-pandemic life.

We present this Discoveries paper in the spirit of engaged scholars (Van de Ven, 2007; Hoffman, 2021) who are problem driven rather than theory driven, so we will not provide a positioning literature review, but address directly the evidence of what has happened. A discussion section reviews the cases for their implications for project organizing theory and a research agenda is be proposed in conclusion. Clearly, we have not engaged in fieldwork in order to collect our cases and vignettes. That has been impossible under current circumstances. Following the example of the COVID-19 response more generally we are offering evidence speedily from sources which are principally journalistic in order to provide a first analysis of what we believe are important changes in project organizing practice.

The international research team use the following criteria for case selection: international applicability where many countries were facing similar challenges and responding in similar ways; a mix of immediate responses (field hospitals; COVID apps) and more strategic responses (vaccines); public availability of information on the cases; and a cut-off of Dec 31st, 2020. We chose these three as the most significant project-based responses to the pandemic during 2020 that met our criteria; there was not enough publicly available information about the other significant response – the establishment of test and trace systems - to enable analysis. Our cut-off date means that we could not examine vaccination roll-out projects. Later, deeper research by others will doubtless revise some of our evidence and analysis, but we believe we will have contributed to project organizing research by taking important first steps in developing that research agenda (Müller and Klein, 2020). We identify, in particular, the importance of radical changes in owner commercial strategy for schedule compression in project delivery.

In order to capture our data we started with an international newspaper of high repute for the objectivity and accuracy of its reporting, the Financial Times, and followed up all interesting leads in real time. This activity was supported by reporting from a broadcaster of equally high repute, the BBC. Wider search was then enabled using Google (English,

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Russian and Spanish) and Baidu (Chinese). For the vaccines case we were able to use Google Scholar as the most comprehensive and rigorous (Hoffman, 2021) of the academic search engines. These data enable us to provide a "first cut" analysis of the commonalities and differences between types of projects (construction; information systems; pharmaceuticals) that are not normally analysed jointly through the shared challenge of schedule compression.

We start by presenting two case vignettes of specific COVID-19 responses that offer insights into schedule compression through agile project organizing in two very different sectors and three different countries. The first is a COVID-19 tracing app in Uruguay; the second is emergency field hospitals in the UK and China. The tech and construction sectors could not be more different in their accepted practices in project organizing, but we can see how construction learned from tech to produce remarkable results in terms of schedule compression. We then move on to our principal case – the remarkable global effort in vaccine development. Although the key players were national governments, the mobilization involved was truly global in terms of oversight, research and development (R&D), field trials, and manufacturing supply chains. In particular, we will see how the removal of liabilities for failure from suppliers enabled unprecedented schedule compression in vaccine development and hence a much more optimistic 2021 for the world than 2020. In our discussion, we explore in detail the implications for agile approaches to project organizing, selectionism in project portfolios, project organizing at pace, and owner commercial strategies that enable schedule compression by suppliers. Suggestions for a research agenda follow.

2. "It was crazy": CoronavirusUY app

"It was crazy… we worked as a team, 24/7… on Friday March 13 we had nothing, and on Friday March 20 we had the app delivered." (Nicolás Jodal CEO of GeneXus, cited Financial Times 13/12/20). At the time, Uruguay had four confirmed cases of COVID, but Jodal instantly realized how an app could support the national response to the pandemic so he mobilized a team of 150 people from 12 firms with the support from the Uruguayan government's Agency for e-Government and Information and Knowledge Society to develop the CoronavirusUY app (Financial Times, 13/12/20). All work was voluntary, free and seen as a civic duty. The app concept built on ideas from China and South Korea adapted to the needs of Uruguay such as interconnection with health stakeholders, provision of telemedicine, multi-channel design (web chat, instant messenger, web form call centres), and accessibility. The challenge was to build the app at pace rather than technological innovation (Milano, 2020). The initial aim was to connect the worried well to healthcare providers to prevent the health system being overwhelmed. Next (two months later) came contact tracing; because they already had the app, Uruguay was chosen by Google and Apple as one of four countries globally to pilot their Exposure Notifications API.

At the start the team did not know if the project would be a success: it was formed by people who had never worked together; there was no development process; no formal communication channels across the team; and there were no written functional requirements. They embraced redundancy by using a number of teams working towards the same goal until a winning approach emerged based on "whichever was first and met quality standards". The team believe three key factors contributed to the success: first, team members were academically strong, second, the country is digitally advanced, and third, Uruguay has a thriving software sector (Financial Times, 25/12/20). The process was described as 'extreme agile'; it was not in alignment with agile principles because there was no scrum, or Kanban and they claim that they did not use any of the processes described in any of the textbooks on the management of software development. Rather, they took an "absolute pragmatic approach where what mattered were those people who had the skills, and that we all understood that the process was a means to achieve the objectives" (Milano, 2020).

This team focus on outcomes rather than the technology lead to remarkable results. The app is credited with helping Uruguay's successful strategy of containment without recurring to mandatory lockdowns and very low infection rates (Fondo Monetario Internacional accessed 25/01/21).

3. "Forget all you know": emergency field hospitals

The UK's Nightingale Hospital programme in response to the first wave of the COVID 19 pandemic delivered seven field hospitals to provide surge capacity for the existing National Health Service England (NHS) hospitals. They cost $302m (all amounts are in US Dollars at current rates of exchange) and were delivered in less than three weeks – mainly located in exhibition centres which were closed due to the pandemic. On the owner side, the programme was initiated from the national centre rather than by NHS authorities. This allowed the establishment of much more rapid, inclusive, problem-solving orientated leadership of the programme (Herring, 2020). The NHS was supported by the military who could advise on logistics and the operation of field hospitals where the triage process is very different from the normal processes in NHS intensive care units, and learned some important leadership lessons (Bohmer et al., 2020). Once delivered, the hospitals were handed over to the appropriate NHS Trusts in the regions because NHS England does not operate hospitals itself.

Rapid mobilization was possible because the Department for Health and Social Care used its existing ProCure 22 framework agreement with Principal Supply Chain Partners (PSCP) suppliers (https://procure22.nhs.uk/accessed 08/03/21). Winch (2010) provides more detail on the earlier ProCure 21 framework. These existing relationships allowed the establishment of a much more rapid, inclusive, problem-solving orientated leadership of the programme. NHS ProCure22 set up a central Project Management Office to coordinate efforts by all 6 PSCPs in the framework and no significant disruptions to delivery were reported.

This case vignette focuses on one of the seven, the NHS Nightingale North West hospital located in the G-Mex Centre in Manchester providing 650 beds. G-Mex had previously been scoped out by the Army and NHS representatives and the decision made to locate there. The Instruction to Proceed was received by the PSCP on 28th March; site works started on 30th March, and the facility was completed on 12th April – a schedule of 13 days. It opened the next day. In this time, the team delivered 750 beds at an effective rate of 30 min per bed. This included 14500 m^2 of flooring; 149 km of cabling; 3.4 km of partitions; and 7.24 km of medical gas pipe.

The PSCP was Integrated Health Projects (IHP) – a joint venture of Vinci and Sir Robert McAlpine with NG Bailey installing services. The design team was Building Design Partnership and Mott McDonald acted as NHS project managers. The key design decisions were bed bay layout and overall layout isolating COVID-secure from other areas. The supply chain resourced these efforts by pulling people off other projects and working 24/7 to get the job done – the workforce on site peaked at 1000. This achievement depended on innovative project management – the key message for the IHP Contracts Manager was "Forget all you know about normal healthcare construction – this is about constant problem-solving" (cited Bowker, 2020:19). As the services contractor stated, "It was not unusual for us to come together as a small group, identify a challenge, and then someone would literally sketch out an answer with pen and paper. We'd then agree it and make it happen" (cited Bowker, 2020: 21).

This constant problem solving was characterized (Bowker, 2020) by:

- reverse engineering; not really design and build, but more like build and verify by design.
- live beta testing of a full-scale bed bay mock-up assembled on day 2 confirming the dimensions needed by the nursing team and partition system layout.

- change control through a process of "see a problem, develop an answer, test it, build it", all captured by an auditable document trail.
- clinical liaison providing the go-between, the translator and fixer joining up the thinking of the clinical teams and the IHP team.

However, the dynamism posed challenges for the Mott Macdonald project managers:

Yes, we needed to crack on – see a problem, develop an answer, test it, build it – but we needed a paper trail too. Timesheets, materials, and orders, all had to be auditable. That's part of our job as project managers, as well as being the interface with the client team (cited Bowker, 2020: 20).

The innovative solutions included:

- Off-site manufacture (OSM) commenced on day one for the partition system and gantry framework carrying medical gas pipe.
- Flooring contractors across the North West worked together to complete the 14,500 m^2 flooring inside the first week.
- Partition installation teams with over 50 men in two shifts working 24/7.
- Six trucks made a continuous circuit collecting medical pipework from the suppliers, delivering it to the factory for OSM, taking finished sections to site, and then returning to the supplier to begin again. In the second week the teams installed up to 30 m of medical gas pipe every 150 s – by day 9 all the beds were connected.

In contrast to this remarkable success in delivering outputs in the form of functioning field hospitals, the Nightingale programme is also an important lesson in the differences between outputs and outcomes in project organizing. The intended outcomes of providing COVID-related health-care services were not achieved. Only the London and Manchester Nightingales treated any patients during the first wave which was peaking just as they opened, and in both cases the numbers were very low. All the hospitals were held on standby during the second wave, but in the end have not been used for their original purpose. Some have been used as "overflow" for non-COVID patients to ease bed-blocking, and they have also been used as mass vaccination centres as that programme has accelerated. They were finally closed on March 31st, 2021.

In Wuhan, China, the 1000-bed emergency field hospital - Huoshenshan hospital - was built between January 23rd and February 2nd, 2020, a schedule of 10 days. It then operated under the jurisdiction and management of the People's Liberation Army. The design of this hospital was modelled after the Xiaotangshan Hospital, built in the suburbs of Beijing in six days in response to the 2003 SARS epidemic. Prefabricated units for fast construction and installation works were designed and supplied. A second Wuhan field hospital, the 1600-bed Leishenshan hospital with the same design, was completed on February 6th with a schedule of 12 days and opened on February 8th. These two hospitals were both closed and sealed on April 15th, 2020 after community transmission stopped in China. The Wuhan municipal government was the owner for both hospitals, which also received funding from the state and donations. For instance, the National Development and Reform Commission announced the allocation of $45.8m to subsidize the construction of the two hospitals on January 27th. The same day, the State Grid Corporation of China announced the donation of $60.2m of physical materials for the construction of the two hospitals. Mindray Medical International Limited (Mindray) had donated a total of about $1.57m of medical devices to both hospitals as of February 24th, 2020.

This achievement was due to two main factors. The first was *top-down mobilization* which allowed the Wuhan government to coordinate a range of project parties and allocate adequate resources within a short timeframe. Wuhan Urban and Rural Construction Bureau (WURCB), after receiving an order from the Municipal Epidemic Prevention and Control Headquarters for the two hospitals, immediately established an Emergency Hospital Construction Headquarters on January 23rd. The Investment and Planning Division of WURCB drafted and compiled construction and supporting emergency fund management measures to ensure the smooth operation of the capital chain for the construction of two hospitals. They reformulated a set of pricing models suitable for emergency engineering and decided to adopt "cost plus remuneration" pricing, which was included in the "Guiding Opinions on Project Pricing".

The Wuhan government was also able to mobilize supply chains for hospital construction. For Huoshenshan hospital, it immediately commissioned the CITIC General Institute of Architectural Design and Research (CITIC ADI) (assisted by China IPPR International Engineering Design Institute) and the China State Construction 3rd Bureau Engineering (CSCEC-3), which designed and built the hospital. CSCEC-3 completed most of the construction work, together with the Wuhan Construction Engineering Group, Wuhan Municipal Administration Company, and Hanyang Municipal Administration Company. For the Leishenshan hospital, the WURCB also set up an on-site headquarters which commissioned the Wuhan Real Estate Group as the project manager, and CSCEC-3 as the general contractor with the Central-South Architectural Design Institute (CSADI) as the design party. CSCEC-3 has strong resource organizing capabilities and rich supply chains, with support from the China Construction Group. The strong resource advantages enabled the steady progress of the two hospitals.

More than 100 subcontractors such as the Wuhan Construction Group and Wuhan Airport Development Group participated in the construction (Wang et al., 2021). The regional utility, Wuhan Power Supply Bureau, requested a power management company (Eaton) to help connect to utility power for both hospitals. In a matter of days, Eaton and its partners and suppliers helped connect the main power supply at both field hospitals and provided the medium-voltage cable accessories supporting hospital construction with intelligent and reliable power distribution. Mindray also helped install over 3000 units of medical devices against time for both hospitals. As the construction of Huoshenshan hospital started, Mindray's Wuhan subsidiary made coordinated efforts, round the clock, to put together a total solution for the emergency field hospital. Mindray was able to mobilize a front-line team with more than 100 members, divided into teams to start work on the configuration, logistics and installation.

The second was *adequate labour supply*. According to Wang et al. (2021), more than 1500 managers and workers were part of the Huoshenshan hospital project, while Leishenshan hospital involved more than 2500 managers and 22000 workers. A lot of employees and workers gave up celebrating the Spring Festival (Chinese New Year) with their family members and joined in the construction of the emergency hospitals. The entire construction process of Huoshenshan and Leishenshan hospitals was supported by CSCEC's digital platform – Intelligent Construction Site – which was built upon technologies including artificial intelligence, cloud computing, and big data (Luo et al., 2020). In this way, more than 100 sub-contract projects, thousands of procedures, and thousands of construction workers could work seamlessly and advance synchronously.

4. "Operation Warp Speed": the global vaccine development effort

Social lockdowns save lives but are unsustainable for anything above the shortest time period. Obtaining "herd immunity" naturally was deemed too deadly by all governments and so the only alternative was to develop a vaccine. The typical time taken to develop a vaccine is measured in years rather than months, so how has it been achieved at "warp speed"? Or, more precisely, in 326 days from the publication of the genetic sequence by the Chinese authorities on January 11, 2020 to the UK licensure of the Pfizer/BioNTech vaccine on 2nd December (www.cepi.net accessed 26/02/21). The key is that project owners (in the form of governments responsible for national healthcare systems) removed the liabilities for development project failure from suppliers (in the form of pharmaceutical companies large and small) by both pre-

purchasing vaccines and funding development projects directly.

Generically, the lifecycle for pharmaceutical development projects follows the typical new product development lifecycle characterized by strong portfolio management and effective stage gates. The basic business model is that the suppliers of pharmaceuticals identify drug candidates – often by working in collaboration with universities – and then invest in their development. Once licensed, the drug is then offered for sale to health care systems. Drug development projects face particular challenges because a candidate drug may fail at any gate for reasons beyond the control of the project team. Simply put, if the drug does not work, the project is stopped (Pisano, 1997). Vaccine development projects face even greater difficulties than most pharmaceutical development projects because 1) safety concerns are enhanced because they are injected into otherwise healthy people; 2) they need to be manufactured at a scale of billions of doses; and 3) the virus may naturally exhaust itself before the vaccine is ready which happened with the SARS-CoV-1 virus which caused the SARS epidemic 2002-4 (Gilbert and Green, 2021). In vaccine development, "the greatest hurdle is translating basic science advances into real vaccines that can be produced in adherence to stringent regulatory requirements on a sufficient scale to have a meaningful public health impact" (Buckland, 2005: 516). This typically costs millions of dollars and takes years (Gouglas et al., 2018), and only about 1 in 10 candidates make it from pre-clinical trials to licensure in 10 years (Pronker et al., 2013). The threats facing vaccine development projects are existential and the potential financial liabilities generated by those threats for pharmaceutical companies enormous.

In response to these threats, vaccine development projects by pharmaceutical companies conventionally move cautiously through tightly managed stage gates as shown in the upper half of Fig. 1 (Gouglas et al., 2018; Lurie et al., 2020). During the pre-clinical phase, candidate vaccines are identified for their potential to protect against the virus of concern drawing on prior scientific research and clinical experience, a process which may include animal testing for safety reasons. The candidate then enters Phase 1 which typically involves 25–30 closely monitored volunteers and principally assesses the safety of the vaccine candidate. Phase 2 follows with hundreds of volunteers, including a control group, to assess whether the candidate stimulates an immune response.

Phase 3 involves thousands of volunteers across multiple countries, half of whom are in a control group who receive a placebo, to see whether the candidate works in practice for different population groups. Phase 3 is a significant investment in its own right which needs to be supported by an initial investment in manufacturing facilities. The length of Phase 3 is indeterminate because it relies upon volunteers becoming infected "naturally" to test the efficacy of the candidate. Phases 2 and 3 are "blind" in that the investigators and participants do not know who has received the placebo. Once the data are in from Phase 3 trials they can be submitted to national regulatory authorities for licensure. Scale-up for volume manufacturing follows. Each of these phases is subject to oversight by external independent monitors to ensure rigor in the evaluation methods – this body is called the Data Safety Monitoring Board in the US. Finally, Phase 4 is monitoring the continued safety and effectiveness of the vaccine during inoculation programmes delivered by health care systems (Kim et al., 2021b). Where the virus generates significant variants, development becomes an annual cycle as is the case with flu vaccines, but without the requirement for extensive trials.

This schedule can often take years because gate reviews need all the data from the preceding phase. Schedule compression in vaccine development essentially involves taking decisions at gates on incomplete information thereby generating the threat of wasted investment if the candidate fails during later phases. Innovations in scientific research had already compressed the pre-clinical phase by "structure-based antigen design, computational biology, protein engineering, and gene synthesis [which] have provided the tools to now make vaccines with speed and precision" (Graham, 2020: 1). For instance, the Oxford/Astra Zeneca vaccine candidate was "designed" drawing on years of scientific research by the Jenner Institute on earlier SARS viruses over a weekend in January 2020 as soon as the genetic sequence had been received (BBC Panorama, 2020; Gilbert and Green, 2021). However, the trial phases are not so easily compressed. Instead, they must be overlapped as shown in the lower half of Fig. 1 (Hanney et al., 2020; Lurie et al., 2020). How was this achieved successfully for so many vaccine candidates for the severe acute respiratory syndrome coronavirus (SARS-CoV2) which causes COVID-19 disease?

In May 2020, Operation Warp Speed (OWS) was created in the United States as a partnership between the Departments of Health and Human Services (HHS) and Defense (DOD)—aimed to help accelerate the development of a COVID-19 vaccine and included a goal of producing 300 million doses of safe and effective COVID-19 vaccines with initial doses available by January 2021 (Government Accountability Office, 2021). OWS has invested an estimated US$18 billion mostly in the late-stage clinical development and early manufacturing of COVID-19 vaccines as shown in Table 1 and currently has agreements in place to buy 455 million doses (Kim et al., 2021a). In order to maximize productive efforts, OWS and vaccine companies adopted several strategies to accelerate vaccine development and mitigate risk. For example, OWS selected vaccine candidates that used different mechanisms (platforms) to stimulate an immune response, including mRNA (Moderna and Pfizer/BioNTech), replication-defective live-vector (Janssen and AstraZeneca), and recombinant adjuvanted protein (Sanofi and Novavax). In this way, OWS executives supported the broadest coverage of available technologies to develop a viable vaccination in the shortest time possible (Baker and Coons, 2020). Vaccine companies also took steps to accelerate development, such as starting large-scale manufacturing during clinical trials and combining clinical trial

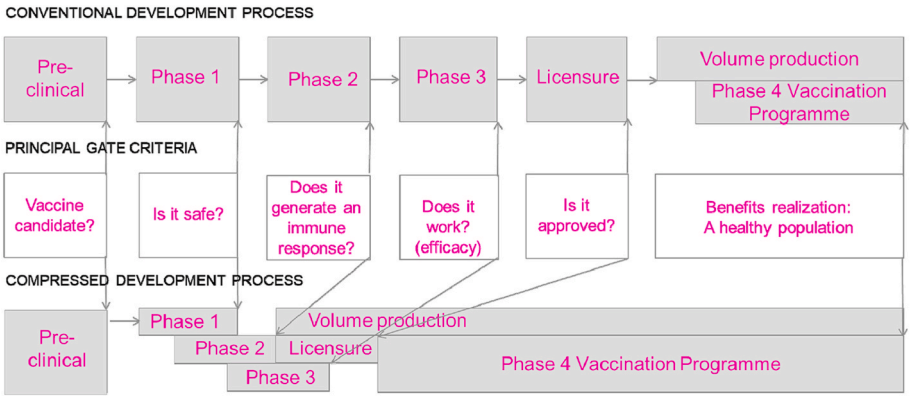

Fig. 1. Schedule Compression in Vaccine Development
Source: developed from (Winch et al., 2022): figure 9.7.

Table 1
Operation Warp Speed Support to Vaccine Suppliers as of 01/03/21 (source: Congressional Research Service, accessed 01/07/21).

Company	Vaccine type	Contract value	Specification	Outcome
Pfizer/BioNTech	mRNA	$5970m	300m doses	approved
Moderna	mRNA	$4940m $945m	300m doses development	approved
Astra Zeneca/ Oxford University	Viral vector	$1200m	300m doses	phase 3
Johnson & Johnson/ Janssen	Viral vector	$1000m $456m	100m doses development	approved
Novavax	Protein	$1600m	100m doses	Phase 3
Sanofi/GSK	Protein	$2040m $30.8m	100m doses development	Phase 2
Merck/IAVI	Viral vector	$38m	development	discontinued

phases or running them concurrently. The U.S. Government Accountability Office's (2020) analysis of the OWS vaccine candidates' technology readiness levels (TRL) - an indicator of technology maturity - showed that COVID-19 vaccine development under OWS generally followed traditional practices, with some adaptations. The U.S. Food and Drug Administration (FDA) issued specific guidance that identified ways that vaccine development may be accelerated during the pandemic. Vaccine companies told GAO that the primary difference from a non-pandemic environment was the schedule compression as shown in the lower part of Fig. 1. To meet OWS timelines, some vaccine companies relied on data from other vaccines using the same platforms, where available, or conducted certain animal studies at the same time as clinical trials. As a representative of Pfizer put it, "the process never changed; it's how we compressed time and it's how we did parallel work that really changed" (BBC Horizon, 2021).

As of January 2021, five of the six OWS vaccine companies had started commercial scale manufacturing. OWS officials reported that by January 31, 2021, companies had released 63.7 million doses—about 32 percent of the 200 million doses that, according to OWS, companies with Emergency Use Authorizations (EUAs) had been contracted to provide by March 31, 2021. There are several factors that hamper rapid scale-up and production of the vaccines, including: limited manufacturing capacity producing bottlenecks, disruptions of manufacturing supply chains, and gaps in available workforce. To mitigate the challenges of supply chain uncertainty and labour availability, vaccine companies and DOD and HHS officials undertook several efforts, including Federal assistance to (1) expedite procurement and delivery of critical manufacturing equipment, (2) develop a list of critical supplies that are common across the six OWS vaccine candidates, and (3) expedite the delivery of necessary equipment and goods coming into the United States. Additionally, DOD and HHS officials said that as of December 2020 they had placed prioritized ratings on 18 supply contracts for vaccine companies under the U.S. Defense Production Act, which allows federal agencies with delegated authority to require contractors to prioritize those contracts for supplies needed for vaccine production. As a result, after initial turbulence in the supply chain and manufacturing, the use of Defense officials and directives has been able to cut through much bureaucratic red tape and ramp up vaccine production.

Thanks, to advances in scientific virology and replication, US pharmaceutical firms felt reasonably confident (regardless of the platform they were employing to sequence the virus and develop a vaccine) quite early in the development cycle that the decisions made would yield positive outcomes. So much so, in fact, that the OWS decision-makers gave the green light to select pharmaceutical companies, like Pfizer and Moderna, to begin ramping up production while the vaccine was still undergoing clinical Phase 3 three trials – as a representative of Pfizer put it a "blank cheque gave us a lot of speed" (BBC Horizon, 2021) to move into manufacturing. This concurrency, coupled with the use of Department of Defense logistics specialists, allowed rapid development and shipment to pre-positioned central receiving hubs, from which the vaccine was distributed state-by-state. Thus, within 24 h of the Emergency Use Authorization (EUA) notification being received on December 13th, 2020, doses of the vaccine were shipped. While final distribution was sporadic (partially due to the decision to allow states to develop their own delivery protocols), millions of doses of COVID vaccines were completed prior to the conclusion of stage three trials and once positive results were determined, immediately distributed to receiving points around the US.

Other western countries also provided support to these same suppliers, as did not-for-profit organizations such as the Coalition for Epidemic Preparedness Innovations (CEPI) which is funded by the likes of the Wellcome Trust and the Gates Foundation, together with some western governments. As implied in Table 1, governments took a portfolio approach to the projects they financed. Western governments typically pre-purchased ~5 different vaccines because they could not know 1) which would survive clinical trials; 2) when they would be approved; 3) how well they would work; 4) how well manufacturing facilities would scale up. As of December 1, 2020, six western countries (counting the EU as one) had ordered four or more doses per capita for a two-dose regime (Financial Times 16/12/20). The remarkable success of the various development projects (only Sanofi/GSK from Table 1 hit major challenges during Phase 2) means that many western health care systems have a potential surplus of vaccines and are starting to make commitments to donating surplus vaccines to COVAX, the international alliance committed to distributing vaccines to developing countries.

The UK took an explicit portfolio approach to vaccine development funding. The UK Vaccines Task Force was established in April 2020 led by a seconded venture capitalist with the authority to "co-ordinate the end-to-end process of vaccine development, from discovery through clinical trials to distribution, including both domestic and international sourcing and licensing" (cited Financial Times 19/03/21), As a result, by mid-February 2021, the UK had ordered a portfolio of over 400m doses of vaccine from seven different suppliers, with the largest orders going to suppliers which committed to establish manufacturing facilities in the UK (Astra Zeneca, Valneva, CureVac and Novavax) each with a different vaccine technology (Financial Times, 10/02/21).

In China, the government used two existing national-level research programmes – the National Key R&D Programmes funded by the Ministry of Science and Technology and the special research programmes funded by the National Natural Science Foundation of China (NSFC) – to fund a series of research and development projects across five different vaccine technologies from January 2020 onwards. The principal suppliers are Sinopharm and Sinovac working closely with universities (Murphy, 2020). By March 17th, 2021, 15 projects had entered clinical trials of which 5 have entered Phase 3. To effectively facilitate and coordinate the development processes of these projects, the Chinese government established a vaccine development coordination group in the Joint Prevention and Control Mechanism of the State Council in January 2020. It comprised 13 ministries including the National Health Commission, the Ministry of Science and Technology and the National Medical Products Administration. This powerful administrative mechanism helped to coordinate more efficiently related resources and facilitated regulatory oversight and approval of these development projects.

One study (Zhang et al., 2021) reports on results of the Phase 1 and 2 trials of the Sinovac CoronaVac vaccine in China; the interpreted results indicate that this vaccine was "suitable for emergency use". From July 2020, the CoronaVac vaccine underwent Phase 3 trials in a number of countries including Turkey, Indonesia, Brazil, Chile and Peru. The results indicate 50% efficacy at preventing disease. The vaccine has been approved and used in high risk groups in China since July 2020 (BBC, 14/01/21). On December 30, 2020 Sinopharm announced that the Phase 3 trials showed 79% effectiveness. Singapore, Malaysia, Philippines, Brazil, Peru, Colombia and Chile have signed deals with Sinovac and Indonesia began its vaccination programme in January

2021 (BBC, 14/01/21). Several nations including the UAE, Bahrain, Pakistan, Egypt, Serbia and Hungary had approved the Sinopharm vaccine by March 10th, 2021 (Financial Times, 10/03/21).

On August 11th, 2020, Russia announced the launch of Sputnik V, adenovirus-based vaccine candidate. The Russian state funded the Gamaleya Research Institute of Epidemiology and Microbiology, Moscow to develop the Sputnik V vaccine (Balakrishnan, 2020; Burki, 2020). Sputnik V is named after the Soviet-era space programme. It has been approved for use in Hungary and is establishing a manufacturing operation in Italy funded by the Russian Direct Investment Fund, the country's sovereign wealth fund (Financial Times, 10/03/21). The Russian Government has approved two other Russian developed vaccines: EpiVacCorona, produced by Vektor Institute in Novosibirsk, and CoviVac, from the Chumakov Centre in St Petersburg. EpiVacCorona uses no live virus and relies on synthetic peptide antigens, based on a selection of those found within SARS-Cov-2. CoviVac uses an inactivated cold virus in the "whole virion" technology, similar to the vaccine candidates developed by the Chinese company Sinovac and the Indian company Bharat Biotech. Scientists in Russia are working on versions of the initial Sputnik V vaccine: one that needs to be stored at freezer temperature, one that can be stored in a range of standard refrigerators and a single dose alternative (Sputnik V light) (Baraniuk, 2021).

Neither the Russian nor Chinese governments appear to have used the pre-order strategy for supporting vaccine development projects but are relying on international sales to recoup their investments. Russia has received international requests for 1 billion doses of its Sputnik V vaccine. For instance, the Russian news agency TASS reported that the country would supply more than 2 million doses of Sputnik V to Kazakhstan. Peru, Argentina, Bolivia and Panama have also contracted for Sputnik V (Horwitz and Zissis, 2020).

One remarkable unintended consequence of this massive public subsidy to vaccine suppliers is a complete reconfiguration of the structure of supply for vaccines. Prior to 2020, the four main global players were GSK, Merck, Sanofi and Pfizer; currently only Pfizer has a viable product. These incumbents are "amazingly large businesses with apparently high barriers to entry. It's very, very expensive to build one of these vaccine facilities," (cited Financial Times 16/02/21) and were perceived as risk averse, preferring to rely on their established approaches. Merck has dropped out completely; GSK and Sanofi are partnering with biotech companies comparable to BioNTech but are off the pace. Astra Zeneca was not a player in the vaccines market until it won the right to develop Oxford's vaccine thanks to its commitment to provide at cost to developing countries through COVAX; it is now the largest global supplier of COVID vaccines. This lack of experience may be behind some of the well-publicized challenges that Astra Zeneca has faced with regulators and contract manufacturers (Financial Times, 26/03/21). Gamaleya has also become a significant player in global markets, although Sinopharm is struggling to make an impact (Financial Times, 09/03/21).

A further schedule compressing innovation is the development of "rolling" regulatory approval (Hanney et al., 2020). Normally, national regulators wait until Phases 1 to 3 are complete before starting their evaluation prior to licensure. The rolling approach involves the regulator in engaging with the data as it is being released by the trial phases, and this, too, has compressed the development process. The output of the development process is a safe vaccine with a known efficacy at preventing infection such as 91.6% for Gamaleya Sputnik V (Logunov et al., 2020). Following licensure, manufacturing facilities can be ramped up and vaccine doses delivered to healthcare systems so that benefits realization can begin and the output of a safe and effective vaccine can be transformed into the outcome of pandemic suppression.

Clearly, there are advantages in being a larger country in this effort, but some smaller countries have also been able to engage with the development process through participating in Phase 3 trials. For instance, suppliers from countries such as China which had successfully suppressed the virus through lockdowns were obliged to test their vaccine candidates in other countries which had been less successful. In June 2020, Sinopharm signed an agreement with the United Arab Emirates (UAE) to implement Phase 3 clinical trials under the supervision of its Ministry of Health and Prevention. In September 2020, the UAE authorised the emergency use of the Sinopharm vaccine for front-line workers, which made the UAE the first nation other than China to authorize the emergency use of a COVID-19 vaccine developed by a Chinese supplier. It later announced on December 9th, 2020, that it had licensed the Sinopharm vaccine – the first nation worldwide to license a Chinese vaccine, including China itself. In January 2021, an agreement to manufacture the vaccine in UAE was announced. Similarly, Israel was able to secure early supplies of the Pfizer/BioNTec vaccine by agreeing to share fully the data collected by their healthcare systems during Phase 4 (Financial Times 26/01/21).

For the western-based vaccine suppliers which remain dominant in global markets, there is a very clear lesson on how schedule compression was achieved. Quite simply, owners in the shape of national governments responsible for their health care systems removed the liabilities for failure at stage gates by providing massive development support direct to suppliers and through pre-purchasing programmes thereby removing the liabilities in the form of wasted investment for the failure of vaccine candidates during trials. This support then unleashed a wave of process innovation (Pisano, 1997) including the introduction of rolling licensure. In combination, these innovations meant that large stockpile of vaccines were available as soon as licensure was achieved to enter benefits realization in Phase 4. There have been many moments of crisis in the global vaccine development programme, and there will continue to be so, but overall the programme has been one of considerable success based on international collaboration in the face of a common threat. In the UK, at least, the crucial decisions taken in April 2020 were consciously seen as an $18.5bn gamble in which the UK decided to "pay high, pay early and ensure that it works … … [but] imagine if it hadn't come off and we had spent all that taxpayers' money" (cited Kuenssberg, 2021).

5. Discussion

In analysing these two vignettes and one case study of project management in action, our approach was abductive (Van de Ven and Ferry, 2007). There is no extant theory that can start to explain the range of phenomena found across our empirical examples. We therefore worked outwards from the core phenomenon of schedule compression to identify the challenges posed for a number of existing theories in project organizing and to suggest new potential theoretical framings. At this stage of our knowledge, this theoretical development regarding the question of why things are so and not otherwise which is at the heart of abduction can only be tentative, and we warmly invite other researchers to take up these questions.

A first theme arising from these vignettes and cases is *agility*. The last 20 years has seen the rise of "agile" methodologies for project delivery, the most popular of which is Scrum (Serrador and Pinto, 2015). However, agile is more than just a project methodology, it is a project delivery narrative (Sergeeva and Winch, 2021) supported by a "manifesto" and proselytizers who are true believers in the new method and its innate superiority over waterfall delivery strategies – it is one type of project delivery DNA (authors, 2022). Agile project delivery works very well for small, stand-alone projects that deliver direct to users who can readily transform the agile outputs into useable outcomes but once agile teams are included within multi-team delivery organizations then problems start (Dikert et al., 2016; Hobbs and Petit, 2017). While the timeboxing inherent in agile methodologies has many advantages, it only possible thanks to flexing scope rather than schedule. Where the scope is delivered to the final user (such as the CoronavirusUY app on a mobile phone), then few problems arise, but once another project team is the "user" of the outputs from the sprints then problems arise if that output does not allow the second team to do its work as planned. The

relative autonomy of agile teams, while having important incentive properties, also poses challenges if they choose to work on aspects of scope that are not priorities at the level of the project as a whole.

The limitations of agile alone encourage hybrid approaches (Bianchi et al., 2020) in which agile methods form part of the delivery strategy within an overall linear project life-cycle. The UK Nightingale case offers some indications of how this might be done. There is no question of flexing scope in a health care facility. Unless everything works to the required standards of care, nothing does – work packages are highly integrated and cannot be time-boxed. The solution was "extreme teaming" (Edmondson and Harvey, 2017) in which project organizing is fundamentally a problem-solving discipline (authors, 2022), not an administrative discipline relying on standardized methodologies. For vaccine development, there is no question of flexing scope for schedule – any vaccine candidate must achieve the highest standards of safety and efficacy against internationally recognized protocols before it can move into Phase 4 benefits realization. One of the reasons for the weaker performance of successful Chinese vaccines in the international markets is the lack of perceived transparency in their adherence to these protocols (Financial Times, 24/03/21; 10/08/21). Vaccine development needs to use schedule compression while retaining the rigour of the waterfall approach. There is a considerable research agenda here around what *agility* in project organizing looks like beyond the standardized agile methodologies, especially as the CoronavirusUY initiative did not follow these in detail either.

The CoronavirusUY vignette, while adhering to broadly agile principles, does reveal some interesting aspects. In essence, Jodal ran a "hackathon" which is a form of crowdsourcing-based open innovation for software development. However, the unusual aspects were incentivization through "civic duty" rather than the cash prizes which were used in European COVID hackathons (Bertello et al., 2021), and the rapid adoption and benefits realization by the Uruguayan government. Interestingly, research on assistive technology hackathons (Lifshitz-Assaf et al., 2021) indicates that the formal agile methodologies break down in hackathons because, ironically, they are too rigid to deliver in extremely schedule-compressed environments.

Hackathons are a particular 21st century example of a much older framework for the management of innovation projects with a history extending at least back to the cash prize for solving the problem of measuring longitude in the 18th century (Sobel, 1996). That prize was funded by the UK government, but more recent initiatives have tended to be privately funded (Eggers and O'Leary, 2009). One example is X PRIZE (www.xprize.org) which is credited with initiating the private sector space flight industry. Further research would be warranted on how the project outputs from hackathons and other forms of open innovation can be transformed into successful outcomes, especially that they are now being used for the development of project data analytics (Project:Hack – Project Data Analytics Community accessed 28/03/21).

A second theme is project *decision-making under high levels of uncertainty*. Traditional approaches to project organizing rely upon "instructionism" in decision-making (Pich et al., 2002) involving detail project planning and extensive use of risk management techniques supported by contingencies to absorb the liabilities for possible threat events. More recent approaches (Morris, 1994; Winch, 2010), stress the importance of learning in the project lifecycle managed through repeated cycles of decision-making structured by stage gates as shown in the upper level of Fig. 1. However, such learning is time-consuming and always faces the threat of unk-unks derailing the project completely. Under very high levels of uncertainty – and we would add severe schedule compression – neither of these approaches is adequate and "selectionism" is preferred defined as "several project teams pursuing different solutions for the same problem and retaining the one with the best outcome" (Pich et al., 2002: 1020). Selectionism is clearly at work in the hackathon approach to app development, and also the schedule compressed approach to vaccine development in the lower level of Fig. 1. However, the vaccine case differs from selectionism in traditional project portfolio management (Pich et al., 2002; Wheelwright and Clark, 1992) because the portfolio is held by the owner (i.e. governments responsible for health care systems) and not the suppliers of vaccines each of which is working on only one or vaccine two candidates at any one time. Selectionism as an owner project portfolio management strategy warrants further investigation.

A third theme is that while project typologies (Shenhar and Dvir, 2007: Fig. 1.2; authors 2022 Fig. 2.6) often identify *pace* as a project organizing contingency factor, there has been remarkably little research on this dimension beyond disaster recovery and emergency response projects. Disaster or emergency management, as a broad term, involves plans, structures, and arrangements established to engage governments, voluntary and private agencies in a coordinated way ranging from prediction and warning to relief, rehabilitation and reconstruction (Moe and Pathranarakul, 2006). Disaster response and recovery projects present unique project management challenges since such projects are often characterized by an influx of stakeholders and organizations working together under extreme schedule and resource pressures, especially local communities and government agencies (Walker et al., 2017; Chang-Richards et al., 2017). When responding to disasters, emergent response groups that use and coordinate non-routine resources, activities and organizational arrangements to apply to non-routine domains and tasks play critical roles in the event of catastrophic disasters (Majchrzak et al., 2007).

The traditional evaluation of project performance as well as the traditional project management methodologies are in many ways not suitable for disaster recovery projects. The changes caused by the volatility of post-disaster environments often calls for an "agile" strategy. Vahanvati and Mulligan (2017) emphasized an agile approach to project planning and implementation in contributing to the project effectiveness for post-disaster reconstruction work, along with allocation of time for gaining and maintaining community trust, provision of sufficient materials, technologies, and skilled labour choices, as well as continued building of community trust and the development of "swift trust" within and across the participating project teams (McLaren and Loosemore, 2019). Resource shortages and supply disruptions are common issues in post-disaster recovery projects. Chang et al. (2012) based on a comparative case study found different resourcing approaches were adopted in different cultural, political and socio-economic environments, but a further urgent question is how this can be rapidly done to ensure resource availability for recovery projects in disaster situations.

There is, however, an important distinction to be made between disaster recovery projects and emergency response projects. In disaster projects which overwhelm the local capacity to respond, multi-national teams are rapidly formed which mobilize to the disaster zone. In emergency response projects, local capacity is reconfigured but not overwhelmed (McLaren and Loosemore, 2019). Wearne and White-Hunt (2014) provide case studies of emergency projects - principally to restore failed infrastructure. In such cases, the project mission is clear – reinstate infrastructure services to their previous levels – but how to do it is not, and the project team is unformed. Although vaccine development and the field hospitals were delivered by existing teams working in new ways, the CornonavirusUY app mobilized people who had not worked together before. More research is required on how project pace as a contingency variable shapes project organizing, particularly in the case of emergency response projects. A further understanding of how emergent response groups rapidly and efficiently coordinate knowledge, resources, tasks, and technologies will surely contribute to understanding project organizing at high pace.

Our fourth theme is the *role of* sponsors. This area has received remarkably little attention in the research on the governance interface (Winch, 2014) in project organizing. The Project Sponsor is a somewhat diffuse and under-developed role in many owner organizations with little role-specific training available (Breese et al., 2020), but it involves accountability for the achievement of project outcomes and is clearly

distinguished from that of the Project Director/Manager who has delegated responsibility for delivering the project outputs (authors, 2021). Effective project sponsors have a significant impact on project performance (Barshop, 2016; Kloppenborg and Tesch, 2015) and need to be able to resolve cross-functional issues (Helm and Remington, 2005), particularly round the allocation of resources to the project. The CoronavirusUY and field hospital projects clearly benefitted from high level administrative sponsorship within government departments which enabled the transfer of resources from other projects with lower priority for COVID-19 response and the authorization of reimbursable payments for suppliers. The vaccine development projects in the USA and the UK benefitted from the personal sponsorship of the President (USA) or Prime Minister (UK) which enabled radical innovations in the commercial interface to achieve schedule compression. We are aware of little research on the implications of sponsorship of major projects by politicians, although this is clearly a widespread phenomenon – the "prince effect" (Chaslin, 1985) is not confined to France.

For our final theme we return to the principal phenomenon that our vignettes and cases reveal – remarkable levels of *schedule compression*. Typically schedule compression leads to inefficient project delivery (Thomas, 2000) which may be an acceptable trade-off in an emergency, but schedule compression can also drive complexity into the project which can cause project delivery over the "tipping point" into chaos as happened on the UK's Crossrail Project (Winch and Msulwa, 2019) and hence much later delivery of outputs than expected. The overlapping of project phases in vaccine development – or concurrency in project organizing terms – can be a major threat to the successful delivery of any complex project (Morris, 1994). How has this been achieved successfully?

Due to resource- or uncertainty-related problems such as constrained project budget and adjusted project objectives, the need for schedule compression, which refers to shortening the schedule duration without changing the original project scope, either through fast-tracking or "crashing" (Project Management Institute (PMI), 2017), have been frequently observed and reported in different types of project practices (Kerzner, 2017; Meredith and Shafer, 2021). While the extant literature has widely reinforced the importance of "technical" approaches such as time-cost trade-off algorithms and resource relocating models (Ballesteros-Perez et al., 2019; Tomczak and Jaśkowski, 2020) for project schedule compression, the vignettes and case investigated in the present study collectively provide evidence for the critical role of managing across the commercial interface (Winch, 2014) as one crucial factor in achieving "organizational" approaches to enabling schedule compression in complex projects characterized as inter-organizational collaborative relations. Inter-organizational relations (IORs), which have attracted increasing research attention over recent years (Lumineau and Oliveira, 2018; Oliveira and Lumineau, 2019; Roehrich et al., 2019), can be defined as "strategically important cooperative relationships between a focal organization and one or more other organizations to share or exchange resources with the goal of improved performance" (Parmigiani and Rivera-Santos, 2011:1109), and concern here is the "vertical" IOR between buyers and suppliers on complex projects.

If we leave aside CoronavirusUY app development because the project was, in effect, decommercialized by casting participation as a "civic duty", we can see that for the field hospitals in both China and the UK, and for vaccine development, the owner removed all liabilities for failing to deliver an output from the suppliers by using reimbursable contracts in which all the costs incurred by suppliers are reimbursed by owners. So, the North West Nightingale project manager's chief task was tracking all the costs incurred by the delivery team working at breakneck speed and reporting them to the NHS for reimbursement to the members of IHP. Fortunately, this was in the context of the collaborative relationships across the commercial interface already established within the ProCure22 framework. There was, therefore, relatively low threat of the project not delivering the required output ready for health care because the output standards to be achieved were clear, and all the resources required – human and technological required were available if only by diverting them from lower priority projects for the same owner.

The case of vaccine development was rather more radical. Owners took on all the risks liabilities for vaccine candidate failure that would normally have been borne by suppliers through both development support and pre-purchase agreements costing billions of dollars. This enabled development projects to move from "instructionism" (Pich et al., 2002) carefully organized to manage the threat of candidate failure during trials to "selectionism" in which competing candidates raced to reach the project completion point of licensure. The result was a complete upheaval in the structure of supply in the sector with suppliers that had never made a profit before (Novavax and Moderna) hitting the jackpot with innovative mRNA technologies (as did Pfizer/BioNTech) and entrepreneurial upstarts (Astra Zeneca) entering the market while established players (Merck, Sanofi, GSK) were apparently trapped by their established ways of doing things. Russian suppliers (Gamaleya) have also successfully entered international markets, and Chinese suppliers will likely follow (Murphy, 2020). IORs have received little attention in project organizing research (von Danwitz, 2018), yet they are clearly central to how projects are organized. Much more research is required on this aspect of project organizing.

6. Research agenda

In our discussion of the case and vignettes, we have identified four themes which we believe warrant much greater attention in project organizing research. These are:

- Agility in project organizing as a project delivery strategy as distinct from agile as a standardized project delivery methodology and project DNA;
- The role of hackathons, competitions and open innovation in project organizing;
- Selectionism as a project shaping strategy at the owner portfolio governance level;
- Pace as a project organizing contingency and schedule compression as a project delivery strategy rather than a technical scheduling problem;
- The role of sponsors – particularly political sponsors – in mobilizing resources for priority projects;
- Relationships across the commercial interface in terms of how they enable (or not) schedule compression and other innovations in project organizing.

In our analysis, there is also a broader set of questions raised by our research into the response-by-projects to the COVID-19 pandemic. Across all sectors of response project organizing has been central. This includes the identification of therapeutic drugs for COVID-19 treatment; the development of mass-scale test and trace systems for infection control; the design and implementation of economic support schemes for individuals and businesses; procurement and distribution of personal protective equipment (PPE) to hospitals and care homes; and – perhaps most crucially – the shaping and delivery of mass inoculation schemes to realize the benefits of the vaccine development projects. Performance on these projects and programmes has, to say the least, been variable around the world with no clear patterns. International comparative analysis of these projects would reveal enormous insights into project organizing in its institutional context (Morris and Geraldi, 2011).

Overall, we can identify a "projectification" (Lundin et al., 2015) in the COVID-19 response which is likely to have much wider ramifications across economy and society. Research on projectification to date has been largely descriptive, analysing the implications of the projectification of society since the mid-1960s as an autonomous process of development. More recent developments have shifted this descriptive perspective to a normative one in which we *should* change to a "mission economy" to address the "grand challenges" we face (Mazzucato, 2021).

It has already been suggested that the UK strategy for vaccine development is a successful example of this new approach (Balawejder et al., 2021). This is an important debate for the all those researchers working on projects as a field of study.

7. Conclusions

In this paper we have provided an initial analysis of project responses to the COVID-19 pandemic by developing two vignettes and one case study from secondary, but authoritative, sources. We worked in the spirit of engaged scholarship driven by the problem rather than the theory, but in doing so we have identified five distinct themes for empirical research into schedule compression for pandemic response – agility, selectionism in portfolio management, pace, project sponsorship, and the importance of the commercial interface in schedule compression. We believe these findings have more general implications for project organizing research. We also identified an important theoretical development to which further analysis of COVID response will likely make a significant contribution – the mission-orientated economy. This Discoveries paper is just a start in what we hope will be a growing research agenda with multiple contributions from across the field.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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