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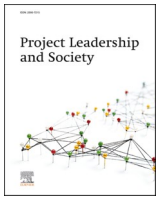

Empirical Research Paper

Socialized leadership and improvisational responding to COVID-19 supply voids

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ABSTRACT

A centrally initiated but collectively improvised voluntary network of disaggregated actors, professionals and non-professionals spread across the globe, in an example of socialized leadership in the form of Open Source Medical Supplies (OSMS). Drawn globally from universities, governments, firms and individuals, OSMS, was a digitally networked project platform to remedy medical supply shortages through the ethos of peer production. We demonstrate how such a globally distributed, but digitally interconnected, network can improvise solutions to grand challenges such as COVID-19. From a practical standpoint, our study offers invaluable insights on effectively mobilizing distributed communities to initiate swift, purposeful projects to mitigate disruptive crises. The dual focus on a central digital platform and its role in facilitating numerous localized, globally distributed initiatives, provides key learning for future responses to widespread issues, such as the PPE shortages witnessed during the COVID-19 pandemic.

1. Introduction

We are used to thinking of projects in quite a material sense, as a piece of built infrastructure, whether an information system, a material communication system such as a train or road network, or as a major urban development. Virtual projects that respond to crisis are different, especially when these virtual projects are not embedded in an organization but are articulated through an actor network that is essentially improvised rather than planned or managed centrally. For such projects, *a priori*, there can be no project budget and no project management planning, no hierarchical structure of established leadership and authority; instead, there are immediate improvised responses.

The exponential and rapid spread of COVID-19 created a disruptive crisis, brought into sharp focus because of its immediacy (Dutton, 1986; Sarkar and Osiyevskyy, 2018). Established supply channels for healthcare services were faced with extraordinary and immediate demands for essential life-saving devices in quantities that overwhelmed just-in-time supply. With little or no stockpiles to run down, significant shortages emerged rapidly. The occasion called for exploitation of "unanticipated opportunities" (Miner et al., 2001, pp. 314–316) in which speed was important. Action was needed within a "time frame … shorter than regular planning" (Moorman and Miner, 1998, p. 1). Improvisation was necessary (Moorman and Miner, 1998; Miner et al., 2001; Kamoche et al., 2017). The improvisation in response to crisis that we will focus on provided "a unique platform for the study of hard-to-get-at organizational phenomena" (Hällgren et al., 2018, p.112) through a virtual project involving social media. When COVID-19 was recognized as such, it was already too late for regular project management to deal with the consequent wide ranging and disruptive implications. Life, organization and work began to be disrupted in ways certainly unimagined by most governments and organizations. Governments, organizations, and individuals were forced to improvise responses, some more effectively than others.

We analyse a voluntary global network of disaggregated actors, composed of both clinical professionals and non-professionals. We develop a process model and uncover how OSMS improvised resources and digital platforms for the production and distribution of PPE, ventilators and other medical supplies, globally. We investigate *who* was involved, *why* they acted, *how* they acted and *what* their actions produced (Buckley and Prashantham, 2016). By embedding improvisation within the context of global challenges, our study provides a novel perspective on how socialized leadership can be digitally distributed

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across unbounded intraorganizational actors purposively connected in a project scrambling to save lives in the face of a catastrophic pandemic that eventually resulted in nearly 7 million deaths at the time of writing. The project aimed to ensure that hard-pressed healthcare professionals on the frontline of care were protected from being part of the toll of death and sickness.

Our research question asks, "*during a disruptive crisis, how are viable solutions identified through improvisational search by an agile network of project actors responding to a grand challenge?"* In answering this question, we first contribute by showing how a globally distributed network of disaggregated actors can collectively improvise a globally distributed project though socialized leadership. Second, we demonstrate that distributed actor networks can deploy resources and solutions for radical innovation in response to grand challenges through digitally mediated networks composed of previously unknown and unconnected agencies. Third, we contribute to the literature on the improvisational use of digital technologies (Yoo et al., 2012; Nambisan, 2017) using social media (Wellman et al., 2003; Majchrzak et al., 2013; Majchrzak et al., 2013), analysing how distributed agencies rapidly formed networks (Garud and Karnoe, 2005). From a practice standpoint, our exploration of this network's successes and challenges provides lessons in responding to a disruptive crisis. Entrepreneurial and socially purposeful actors formed rapid actor networks that filled the institutional voids exposed (Sarkar et al., 2022). In what follows, we begin by discussing the theoretical theme of improvisation, before moving to a discussion of the research context and methods. The findings, as they relate to the theoretical themes are then presented, followed by a discussion and conclusions.

2. Improvisation and socialized leadership

2.1. Situating improvisation

Without preparedness, organizational improvisation tends to be ad-hoc and singularly episodic, rather than facilitating systemic organizational change and transformation, according to Simpson and Clegg (2023). The improvisation that we pry open systemically changed many organizations globally by providing local means for filling institutional voids that resulted from supply chain disruptions caused by COVID-19. Weick (1998, p. 544) aptly observed that improvisation "deals with the unforeseen ….it works with the unexpected", and COVID-19 was both unforeseen and Open Source Medical Supplies' (OSMS) response to it was unexpected, in that it was not planned. Moorman and Miner (1998, p. 5) note that improvisation occurs when "unexpected jolts or surprise … make prior plans irrelevant or incomplete." COVID-19 was an unexpected global 'environmental jolt'. Prior research highlights improvisation by firms needing rapid responses to changing demand conditions (Egge, 1986). COVID-19 created changing demand conditions to which existing firms could not respond quickly enough to meet escalating demand. Eisenhardt and Tabrizi (1995) found improvisation effective when an industry faced rapid changes, when sticking to plans is unwise, as Crossan et al. (2005) noted. COVID-19 threw the existing industry for PPE production, largely concentrated in supply chains that began in Asia, mostly in China, into a situation where the immediacy of demand could not be met. Eisenhardt and Tabrizi (1995) observe that improvisation flourishes when unexpected events create a need for organizational action while simultaneously weakening routine planning. COVID-19 disrupted routine planning of the supply of PPE by massively precipitating a demand for equipment whilst simultaneously minimizing supply through disrupted supply chains. Miner et al. (2001, p. 312) noted that engineers searching for solutions can create "unanticipated" opportunities for improvisation. Such opportunities act as "referents" for improvisation (Miner et al., 2001, p. 316) and as an "impetus for improvisation" (Cunha et al., 2012, p. 269). Software platform engineers produced OSMS as an improvisation in the face of COVID-19 that could link legitimated designs of PPE with fabricators globally.

In emergency responses, the relatively short time frames available for improvisation demand "rapid moves" (Cunha et al., 2012, p. 270) to "[snatch] sudden opportunities" (p. 268). COVID-19 struck with a ferocious and escalating decimation. Weick (1979, p. 102) noted that, while most organizational action represents "a mixture of the recomposed and the spontaneous" in a "truly novel situation", there is no past analogous experience to draw on (Weick, 1998, p. 551). Prior to COVID-19, past experience was of regular supply of PPE materials in an orderly manner, as needed, with a predictable demand curve. COVID-19 produced an exponentially increasing and wholly unexpected demand curve. For Baker et al. (2003), the lack of past analogous experience during improvisation implies temporal and substantive convergence of new ideas and their implementation, as do Moorman and Miner (1998, p. 3), reflecting on a narrowing "time gap", making "design and implementation of an activity" more proximate (Moorman and Miner, 1998, p. 3). The COVID-19 situation echoed Weick's (1993, p. 6) observation of there being "no split between design and production" during improvisation. OSMS was a digitally mediated, instantaneous response to the onset of the COVID-19 pandemic,

Improvisation is distinguishable from random, unplanned actions as well as systematic innovation (Cunha et al., 2016). Systemic innovation represents planning prior to action, while improvisation is *intentional* action that occurs without advance planning (Cunha et al., 2016). OSMS was not planned in advance; it was an instantaneous response to an immediate situation that few had envisaged. Eisenhardt and Tabrizi (1995, p. 106) see planning as futile "when the environment is changing rapidly and unpredictably" and COVID-19 proved that, with respect to existing supply systems of PPE, this was true. Improvisation provides solutions to unexpected complex problems (Moorman and Miner, 1998) building upon premises prepared by existing resources that can be material, cognitive (e.g., explicit, or tacit knowledge and mental models) or social (e.g., relationships, behaviour norms). In this case, OSMS emerged out of the prior experience in the digital sphere of an initially small actor network.

Prior literature on knowledge flows across business domains (Cattani, 2006) and open source/peer production (e.g., Benkler and Nissenbaum, 2006; Gershenfeld, 2005) is useful in situating the digital project that we researched. The emergence of pervasive digital technologies (Yoo et al., 2012) produced an increasing trend towards more "democratized" and "distributed" agency. Distributed agency (Garud and Karnoe, 2005) has received limited attention in relation to improvisation (Wellman et al., 2003; Majchrzak et al., 2013). Improvisation gains significant speed, scale and scope from the variability, scalability, expandability and generativity afforded by online platforms (e.g., Garud et al., 2008; Nambisan, 2017). The knowledge required to respond to disruptive changes connects a wide range of activities (Granstrand et al., 1997; Roy et al., 2018), near and distant (Teece, 1992). Previously unnetworked and diverse actors in different domains engaging in rapid knowledge transfers through a digital platform, can create actor networks to achieve intertemporal economies of scope (Helfat and Eisenhardt, 2004). OSMS connected designs for PPE, that were curated, tested, and legitimated, with fabricators able to meet local demand globally. Rather than centralized nodes of supply and distribution, supply was highly distributed. What was centralized was the rapidly innovated digital platform that was OSMS that functioned as the central node in the global network it made possible.

Most literature on improvisation focuses largely on organizationally 'bounded improvisation' (Moorman and Miner, 1998) within formal existing structures and organizations, whether start-ups or established firms (Busenitz and Barney, 1997). Improvisation has been seen to occur through leadership that affords minimal structuring, experimentation, undistorted communication and organizational learning (Macpherson et al., 2022), features that empower creativity (Schildt et al., 2020). The features defining improvisation are usually seen in a specific organizational context, with the most famous example probably being Weick's

(1996) analysis of those wildfire fighters that followed the leadership of their foreman in dropping their tools in the face of a ferocious fire, improvising and surviving, whereas those that stuck to organizational routine, perished.

2.2. Situating socialized leadership

We situate improvisation in a process of socialized leadership whose defining feature was that it did not occur with an existing organization, but rather was an act of creation of a virtual organization born global and born fast as an actor network (Latour, 2005). The project network was digitally enabled, improvisationally, in a manner rarely seen in project management (Clegg et al., 2021b). There was not so much a project leader as a project curator responding to and creating a new kind of 'socialized leadership' (Whyte et al., 2022) that was virtual. Socialized leadership of projects is attuned not just to project completion on budget, on schedule and scope but also to a commitment to broader based value in projects (Clegg et al., 2021b).

The term 'socialized leadership' draws attention to how project leadership responsibilities, may be more distributed or centralized, suggest Whyte et al. (2022). In this paper we research a project based network that arose not by being *either* more distributed *or* centralized but by being *both* centralized *and* distributed. The project network was socially situated in one crisis and platform as well as in many countries and regions thereof. The project moved fast from conception and set-up to delivery through conceptual design, detailed design, testing and implementation, in a matter of weeks. Leadership, rather than vested in a hierarchical authority, occurred in the panarchical relations and practices inscribed in actor networks managing such flows of activity. Networks of actions, relations, language, practices, configurations and assemblages of actants and technologies enabled informal and formal forms of leadership across a major interorganizational project. The context was one of responding improvisationally to the collapse of supply chains and just in time provision of PPE that occurred in COVID-19. The shortages of PPE were a result of an institutional void (Sarkar et al., 2022) created by supply disruptions that challenged the resilience (Giustiniano et al., 2019) of healthcare provision in a pandemic.

Unlike the Uruguayan vignette presented by Winch et al. (2021), OSMS' actor network was mobilized using neither corporate nor government agency. OSMS was a curated website and social media that enabled global actor networks to assuage local supply shortages in their respective contexts through distributed and self-managed organizing as a temporary project-based actor network rather than a formal project organization. The network produced lifesaving equipment in the absence of normal supplies. OSMS provided "high quality information, platforms for collaboration, and strategic support so that members of our community have a diverse ecosystem of support for their efforts" (quotes from https://opensourcemedicalsupplies.org/about/). Unlike the resilience researched by Lee et al. (2020), which mobilized and improvised through place-based networks ties with access to resources, OSMS was not place based but globally distributed. While Lee et al. (2020, p. 439) focused on "social systems as embedded within physical systems (and vice versa)", OSMS was neither place-based nor an already embedded social system within a physical system. Rather than place specific, it was a globally diverse ecosystem sustained by an Internet platform acting as a nodal point. It arose not from an existing social system embedded in a physical system but built a resilient response to an institutional void virtually (Sarkar et al., 2022).

In the absence of any actually existing organization being able to respond with the rapidity required to produce equipment to ensure the safety of front-line healthcare personnel, COVID-19's disruptions posed "a life and death process". Existing organizations and leadership failed to address satisfactorily one major consequence of what was a rapidly evolving contagious crisis; the virus was spreading exponentially, at the same time as supplies of personal protective equipment (PPE) and ventilators were in short supply. The OSMS project emerged as a process in response to a crisis requiring "effective organizational improvisation" (Ciuchta et al., 2021: 289). Chesbrough's (2006) widely cited definition of open innovation as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" had no purchase in this situation. There was just a virtual actor network rather than an organization "inside out" or "outside in". The platform socialized a leadership that was empowered, legitimated and distributed.

COVID-19 occurred fast and so did our research into the responses to it. Just as governments and big pharma had little time to prepare and plan their responses to the pandemic, neither did researchers. To capture fast forming response to a global crisis requires considerable improvisation in research methods. There was no time in COVID-19, especially in the early stages, for careful questionnaire design, while face-to-face interviews became extremely difficult as interactions became potentially dangerous to health. More naturalistic approaches were required and so we turned to inductive inquiry.

3. Methodolgy

3.1. Research approach and phenomenology

Most social science data is manufactured in that it consists of responses to prompts initiated by the researcher. Manufactured data cannot exist apart from the intervention of the researcher. These interventions are typically designed as prompts deduced from hypotheses formulated beforehand and communicated through questionnaire instruments. Prompts need not be hypothetico-deductive; they can be inductive or abductive, the latter being induction disciplined by theoretical sensitivity. These other prompts are more spontaneous and consist of interview questions, designed to elicit 'accounts. Still, these are responses to prompts; without researcher interventions they would not have existed.

By contrast, naturalistic data requires no questionnaire or other stimulus introduced to respondents. Naturally occurring data is all around us and it is surprising that more use is not made of it in analysis. In project management this approach has not been much deployed, although it has been used in research conducted on a project site by Clegg (1975), whose data consisted of audio recorded naturally occurring conversations collected in a project management site office over several months. More recent accounts of the naturalistic approach by sociologists such as Silverman (2021) and project management scholars such as Ninan (2020), rethink the nature of methods in social research. Following their direction, we have largely used naturally occurring primary sources, including documents posted on the Internet, reports and archival material posted on virtual sites such as Facebook and Slack. All this discursive data falls into the category that Ninan (2020) refers to as external online naturalistic data that is available publicly. Given that such data is publicly available no ethical clearance or informed consent was required (Ninan, 2020).

In living memory, no contemporary global phenomenon has been more significant than COVID-19. We engage inductively with the accumulation, ordering and analysis of historical evidence, focusing on the early stages of the pandemic in 2020 and responses to the shortage of PPE that occurred. We deploy case evidence to explain the spread of virtually mediated improvisational actor network responses to the shortages of PPE during the pandemic. We combine interpretive understanding of the purpose behind the actor network formation with a process account of the casual factors involved in producing resilient responses to the institutional void in supply created by the pandemic (Sarkar et al., 2022). Our research approach takes the network as the unit of analysis and investigates the phenomenology behind formation and improvisation. The approach is inductive (Allen and Davey, 2018) historical narrative analysis (Maclean et al., 2016) of a highly accelerated and condensed time of innovation in response to a crisis. The

account privileges storytelling and argumentation, drawing on primary sources generated 'naturalistically' in a compressed but fast changing period. We produce a process model of the "why-who-how-what" that acted as triggers for actor network improvisation enabled by Project OSMS that produced collaborative prototyping of PPE.

3.2. Data collection

We restrict ourselves largely to documented data from an early period in the short intensive history of OSMS. Data collection primarily relied upon social media posts to illustrate "representative" network interactions (Table 1). Hence, our data is primarily digital. Project studies using news media articles (Ninan and Sergeeva, 2021), social media posts (Williams et al., 2015; Lobo and Abid, 2020; Ninan et al., 2019), and digital innovation databases (Ninan et al., 2022) are an emergent phenomenon in project management. As research moves more into the field of digital data a more encompassing conception of the nature of a project emerges. A project becomes feasible that is entirely centrally facilitated, virtual and de-centred in its delivery.

Table 1
Data sources.

	Source	Data type	Citations
Primary sources	Interviews with 5 key OSMS participants from the USA	Quotes and perspective on OSMS history, experience, and opinions	Written and verbal interviews, cited as "personal communications"
	OSMS Facebook group with 73,8000 members and around 7000 pages of posts and comments (public)	Quotes from posts and comment threads; quantitative data on numbers of posts and members per time	Statistics from Facebook CrowdTangle, cited as "CrowdTangle Team, 2021"; top posts identified through CrowdTangle search cited as "OSMS Facebook"
	OSMS Slack with around 1300 users and 37 public channels (private)	Discussions on strategy and engineering designs	Cited as "OSMS Slack"
Secondary sources	OSMS 75-page final report and survey analysis representing 1878 individuals and groups	Combination of three community surveys, including quotes and experiences	Quotes and combined survey data cited as " Cavalcanti et al., 2021"
	Other reports and media interviews	Variety of news articles, academic articles, and personal blog posts	Quotes and data cited according to source
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Primary sources	Interviews with 5 key OSMS participants from the USA	Quotes and perspective on OSMS history, experience, and opinions	Written and verbal interviews, cited as "personal communications"
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	Other reports and media interviews	Variety of news articles, academic articles, and personal blog posts	Quotes and data cited according to source

Not all of the data was naturalistic. Additional individual interviews were conducted with Gui Cavalcanti, a prime mover in the network, along with two other OSMS administrators, and two U.S. OSMS participants who ran local chapters, all of whom gave informed consent in accord with the ethics policy of the university of the interviewer. The interviews were conducted online with respondents in the U.S. We also conducted participatory action research (McIntyre, 2007) in a naturalistic vein. One author joined the main OSMS Facebook group and OSMS Slack soon after the inception of the initiative in March 2020 and participated in periodic zoom calls throughout March–August 2020. Finally, we conducted a post hoc data analysis using CrowdTangle Team (2021), a public insights tool owned and operated by Facebook. We registered with CrowdTangle and agreed to act in accordance with its policies (CrowdTangle 2023), and furthermore only quoted directly from comments that were posted in public groups in which Facebook states, "Anyone can see who's in the group and what they post" (OSMS Facebook 2022).

Surveys conducted and collated by the OSMS staff in their final community report (cited throughout this paper as Cavalcanti et al., 2021) were also used, including two community surveys OSMS conducted from late 2020 involving three separate non-profit organizations, as well as a series of weekly production surveys via the OSMS Facebook page starting in March 2020, representing 1878 individuals and groups forming actor networks collaborating in the production of medical requisites. Half of the actor networks consisted of fewer than five people, nearly half of them ranged from 5 to 100 people, with about 10% with a population ranging from 100 to 4000. The responses collectively represent the actions of at least 42,000 people. Survey respondents were 71% U.S.-based (from all 50 states), but OSMS respondents alone represented 86 countries with fab labs in 130 different countries (Cavalcanti et al., 2021). OSMS started out as a primarily English-speaking and US-based network, acting as a network-of-networks by gathering representatives from a variety of international networks reporting back to local regions (including Israel's Tikkun Olam Makers, India's M19 Collective, Brazil's ProtegeBR, Italy's Coronavirus Makers, etc.).

3.3. Data analysis

We used CrowdTangle to highlight top-performing Facebook posts (along with their respective comment threads) across ten public OSMS Facebook groups. Top-performing posts and comments were sorted based on the category of interaction and analysed to identify first-order concepts CrowdTangle Team (2021) CrowdTangle's chronological analytics enabled exploration of actor network evolution. Most posts referenced come from the main OSMS Facebook page (cited as OSMS Facebook), which reached a peak of 73,800 members in mid-May 2020. Researchers complied with all ethical guidelines required by CrowdTangle and all Facebook quotes cited are public domain. We received permission from OSMS Facebook administrators to cite posts anonymously. Personal communication with key participants, both ongoing and post hoc, supplemented the community responses documented (cited as personal communications).

The actor network was triggered by the virus' effects on supply chains and provision of PPE for health workers. The key nodal points of the actor networks were, on the one hand, the virus as an actant and the platform as an actant. The one was a force of natural evolution, while the other was a sociomaterial artifact rapidly designed in response to the natural actants' effects. We have represented the relations between the two actants and the actors that the platform actant was able to mobilize and to connect in Fig. 1 below, showing the actant-actor network.

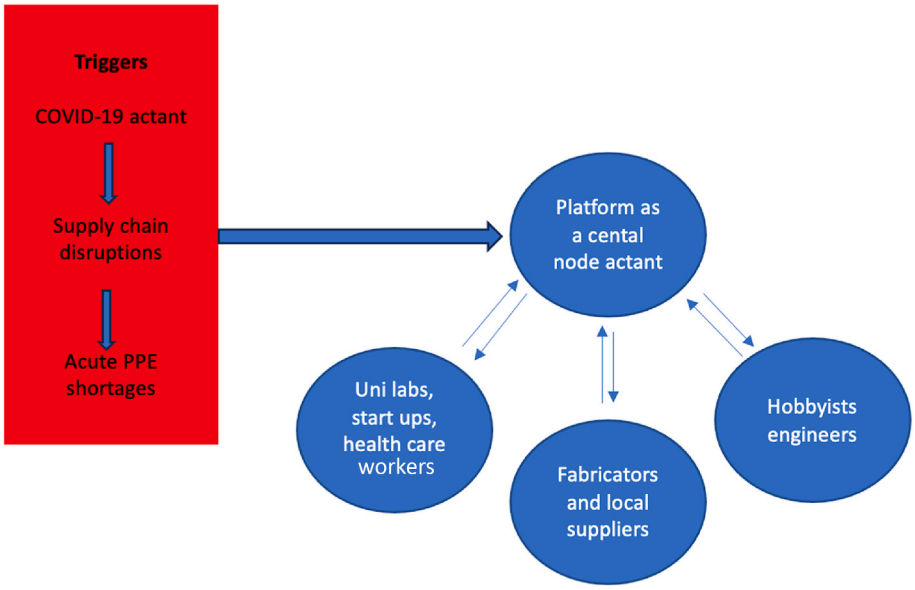

Fig. 1. Actor-actant network.

The actors creating and expanding the actor-actant network did so by designing the platform as a sociomaterial artifact to deal with the consequences of the virus. The arrows connecting the platform actant with the actors were discursive conduits as designed were offered, revised, legitimated and connected globally. At the core of these processes were agential improvisations and collaborations, facilitated by the platform's digital technology affordances. We represent the agential improvisations and collaborations in Fig. 2 below, which inductively ties together the elements of the actor network researched, using a framework that is organized by asking "why-who-how-what" acted as triggers for actor network improvisation that produced collaborative prototyping of PPE through project OSMS.

The prime mover in the creation of the actor network was the actant virus, COVID-19, to which the sociomaterial platform actant was a response. COVID-19's rapid spread confounded existing just-in-time supply schedules at the same time supply chain movements were disrupted because of workers contracting the virus as well as borders being closed. The actors in the process were the networks of makers, fabricators, manufacturers, hobbyists, professionals, laboratories, start-ups and health care workers virtually connecting globally through OSMS. The project purpose was limiting contagion and deaths through creating alternative and substitute PPE. In the absence of standard manufacture and supply and the collapse of just-in-time procurement policies, a myriad of local projects emerged to try and create substitute products for those unavailable, coordinated through the network nodes of Project OSMS. Random improvisation was channelled through OSMS, rapidly becoming an obligatory passage point (Clegg, 2023) for collaborative prototyping in the network, making global connections possible, with specifications defined in one place being rapidly available online for anyone to use.

The narrative that emerges from the findings represents the sociomaterial arrangements depicted in Fig. 2 as a structuration of process flows. The affordance of the platform technology was a necessary but insufficient condition for triggering a potential problem-solving capability. An affordance is not something inherent to a technology; it relates to its sociomateriality. The users of the platform assembled sociomaterial arrangements to connect the platform technology to their goal of providing PPE locally. The PPE produced was an effect of the materiality of technological artifacts, such as 3-D printing and the socio-organizational context in which the technology was deployed (Orlikowski, 2010; Parchoma, 2014). The curational process of the platform served as the nodal point connecting platform design, content providers and local fabricators. Particularly important in the socio-organizational contest was the legitimation of PPE designs by various health authorities and practitioners. It was these local socio-organizational interrelations that shaped relation between the platform and the fabricators through the dual nature of project OSMS. On the one hand it was a repository and dialogue of designs; on the other hand, it facilitated a globally decentred but locally relevant fabrication of PPE for use in globally distributed healthcare facilities. What made all this possible was the socialized leadership that empowered global improvisers and collaborators that the platform enabled.

4. Findings: distributed improvisation agency

4.1. COVID-19 duality and socialized leadership

Without COVID-19 rapidly becoming a global pandemic in March

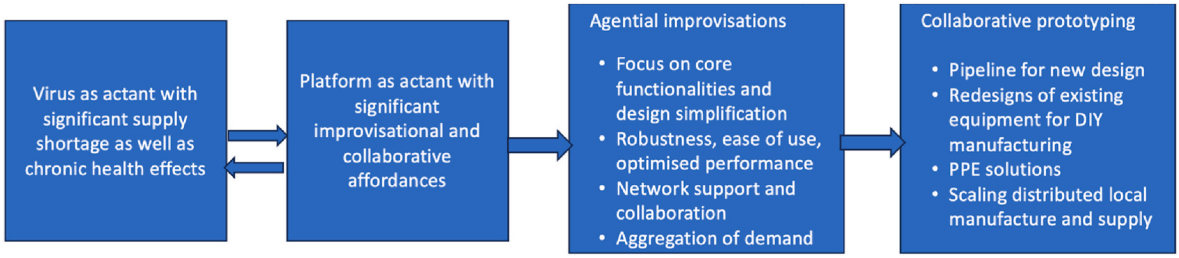

Fig. 2. Agential improvisations and collaborations.

2020, all that we will discuss would not have occurred. In this sense, the virus is the key actant in the narrative, the stimulus that became the occasion for improvisational effects that we will discuss. As we have emphasized, there is no automaticity to these effects; they were a creative improvisational project that proved capable of launching a multitude of fabrication projects worldwide.

The OSMS project displayed duality. As an object of study, it exhibited a 'twofold character' (Farjoun, 2010, p. 203). It was created as a duality: it was *both* a platform *and* functioned as a central node in creating a global actor network that connected curation, legitimation and fabrication through a new kind of distributed and empowered project leadership. From a duality perspective, organizational opposites form one another. The opposites in this case were a centralized platform and a highly distributed network of local fabrication. Project OSMS connected the legacy of peer production as distributed, panarchical rather than hierarchical, centred on a platform that responded to COVID-19 as a 'grand challenge'. It is an excellent example of Whyte et al.'s (2022) 'socialized leadership', leadership that both exercises initiative in accruing powers centrally and that gives these powers away by empowering a global actor network. Socialized leadership is enacted in practices and interactions (Crevani et al., 2010) distributed across interorganizational projects and the contexts in which they deliver, where project contexts are in flux and delivered in the context of changing technologies and organizational dynamics. Socialized leadership is a distributed set of practices, enacted in a continuous social flow (Crevani et al., 2010), that deals with a complexity of values. For the case in question, these values above all, were to save local lives by designing PPEs that would be legitimate in the eyes of its users and their employers. Fabricating and manufacturing was local, to meet local needs, while responding to the greatest challenge in global health terms that had been seen in over a hundred years. Digital information that was shareable, accessible remotely, searchable and up to date, as well as being legitimated, enabled these extensive new forms of global integration and shared leadership. PPE was created that did not rely on existing supply-chains, intellectual property owners, operators or users (Whyte et al., 2022). Shared purpose was collaboratively co-created across a multitude of project digitally connecting a global actor network of local leadership and central curation.

4.2. Legacy of peer production

OSMS emerged from the global Maker Movement, a global, distributed network of shared community equipment for small-scale manufacturing consisting of Fab Labs, makerspaces, and hackerspaces as well as online communities (Gershenfeld, 2005; Dougherty, 2012). Several thousand community innovation spaces shared a set of open-source values, with a semi-standardized assortment of equipment and materials designed to let anyone come in and "make (almost) anything" – from aquaponic sensors to drones to full-size wooden houses (Gershenfeld, 2005). As an actor network, Project OSMS was rooted in "peer production," defined by Benkler and Nissenbaum (2006, p. 394) as "collaboration among large groups of individuals, sometimes in the order of tens or even hundreds of thousands, who cooperate effectively to provide information, knowledge or cultural goods without relying on either market pricing or managerial hierarchies to coordinate their common enterprise." Chalet et al. (2020) state that informal manufacturing networks proved more effective than governments or free markets in mobilizing short-term production during COVID-19.

4.3. The why: the trigger event

The US and the EU import 70% of face-nose protection equipment from China, which produced half of the world's facemasks. During COVID-19, China placed export restrictions on its PPE to protect Chinese citizens first (O'Keeffe et al., 2020). In the USA the Strategic National Stockpile held only 1% of the face masks necessary to address a "full-blown" coronavirus pandemic in March 2020 (Cohen and van der Meulen Rodgers, 2020). Markups during the pandemic drove prices up between 100% and 1000%, a situation so drastic that organized criminal groups, such as drug traffickers, turned to illicit PPE sales (UNODC, 2020). By May 20th, 2020, 87% of nurses working with COVID-19 patients, surveyed by the US National Nurses United, had to reuse single-use disposable respirators or masks.

4.4. The who: the actors making the network

OSMS began as a Facebook group called "Open Source COVID-19 Medical Supplies," created in March 2020 by makerspace founder and entrepreneur Gui Cavalcanti and friends as a response to the pandemic. A globally distributed network of "Makers" started improvising solutions to shortages (Vesci et al., 2021; Pineda et al., 2021). The need for PPE saw a community of diverse practices form, with OSMS the locus of network activities. OSMS served a critical role in aggregating ideas from various communities. Their Facebook group jumped from under 1000 members on March 17 to 15,000 members on March 18, and 20,000 members the following day, showing the convergence between composition and execution. Membership tripled to 60,000 members within ten days and reached a maximum of nearly 74,000 in May 2020. Following the rollout of vaccines and increased availability of industrial PPE, as well as the loss of emergency funding and donations for makerspaces, some members of the community continued to produce PPE, while others transitioned to large-scale production of their designs (Cavalcanti et al., 2021).

OSMS' "Citizen Maker Response" was a heterogenous assembly of volunteers with different skill levels, production experience, and degrees of professionalization. Table 2 below, summarizes the different actors involved in the distributed network that emerged. The final OSMS report, released in March 2021, reported that the network had produced over 48.4 million units of personal protective equipment and medical supplies across 86 countries (Cavalcanti et al., 2021).

In what follows, we report on how a varied set of actors improvised on a globally distributed basis in response to the COVID-19 crisis, in unbounded improvisation (Ciuchta et al., 2021)., Vordos et al. (2020) estimated the involvement of over 140 different social media groups and more than 18,000 individual makers involved in 3D printing from January through April 2020. The Forbes Technology Awards recognized "Makers" as the 2020 Most Disruptive Innovator of the Year. Many of these items represented novel usages of materials and/or production techniques and frugal redesigns of existing technologies, while some items, such as ear savers and intubation boxes, were entirely novel inventions. There were other independent mask-sewing efforts and other improvisations (such as garbage bag gowns, astronaut costume PAPR gowns, and file-folder face-shields) and many small manufacturers who pivoted their factories (i.e., from liquor to hand sanitizer, or apparel to PPE) as well, outside of the OSMS project.

Table 2
Actors in the OSMS distributed network.

Actors	Solutions offered
Medical professionals	Technical feedback on designs, quality testing support, request for supplies
Manufacturers/Inventors/ Designers	Physical supplies, designs
Nonprofits and corporate sponsors	Materials donations, financial support, grant opportunities
Experienced designers and engineers	Designs, technical feedback on designs, design for larger-scale manufacturing support
Academics	Technical feedback on designs and testing, lab capabilities, access to production equipment and assembly space
Makerspaces/fab labs	Access to production equipment, assembly space, and networks of enthusiastic hobbyists and engineers

4.5. The what: improvisational design, prototyping, development and distribution across social media/slack

The unprecedented convergence of ideation, design, prototyping, production and distribution that was enabled by the OSMS community is displayed in Table 3.

4.6. Improvisations in production scale-up

An improvisational approach to material and methods enabled by the platform was created by OSMS as a network of diverse actors through the exposure and introduction online of individuals to others doing similar work (often through Facebook, Slack, or personal introductions). These networks were twice as "helpful" as the multitude of demand-matching platforms and 3.5 times more "helpful" than OSMS project library (Cavalcanti et al., 2021). One striking form of improvisational networking was the connection between hobbyist makers (with ideas and prototyping expertise) and university researchers (who had the equipment and scientific knowhow to test viable solutions). The lack of any existing coherent infrastructure for the tens of thousands of volunteers seeking to pitch in to making PPE spurred a very high degree of improvisation. OSMS was a project that responded to need in the absence of any pre-existing open source approved emergency medical supply designs; almost all were developed during the pandemic. No venue for healthcare workers to request products or even discuss designs with inventors previously existed while hospitals' contracts limited them to a few producers of medical suppliers.

Within a month of its origin, OSMS was able to evolve from a free-for-all Facebook group to a comprehensive design curation pipeline whose project was to vet and medically approve PPE designs. Its Facebook group developed overnight, refining the governance process over several months. Formal channels took much longer; it took 19 days for the state of Massachusetts to launch a matchmaking platform to provide grants and demand signals to support formal-sector firms in manufacturing PPE for state-wide healthcare facilities and 30 days before signing a contract with a small, non-PPE manufacturer for 1 million medical gowns on April 9, 2020 (Reynolds et al., 2021); by contrast, the OSMS community had already produced 840,177 units of PPE across 900 different facilities by April 10, 2020 (OSMS Facebook tally 2020). OSMS's reported output grew an astounding 653% between week 1 and week 6 of the pandemic. Products ranged from one-offs to small-batch production within makerspaces, to full-scale manufacturing over several months (Cavalcanti et al., 2021). The network's dynamism was evident in the rapid transition of products such as face shields from slapdash, taped-together plastic bottles to safer and sturdier 3D printable shields that could be printed 10 in a day on a single printer; to laser-cut models that could be produced several times faster than 3D printed models; to injection-mouldable designs manufactured in their thousands across small and medium factories (Pineda et al., 2021).

Table 3
Forms of improvisations.

Improvisations	OSMS and Community Activities
Production scale-up	Networking designers and producers Connecting supply and demand International information-sharing Scaling hobbyist designs to large-scale manufacturing
Emergency supply chains	Connecting materials and producers Fulfilling small-batch orders that couldn't be met by formal manufacturers Fulfilling rural demand
Safety and liability prevention	"Donations" to limit liability National certifications: Face Shield (EU certified), isolation gown (Philippines certified)
Material testing	University chemistry labs testing N95 materials Makerspaces collaborating with local hospitals, fire departments
Rogue procurement	Makers going around official hospital guidelines Brazilian supply-demand networking platform Healthcare workers independently bargaining for own supplies
Curation and priority-setting	Collaborative discussion platforms: Facebook posts and comments Slack for detailed engineering discussions Googledocs for sharing camera-ready (yet still changeable) production documentation
Design selection and rapid feedback, leading to reliable, manufacturable designs	DIY Face shields Ear Savers Mask sterilization boxes Other supplies Repair parts

4.7. Improvisations in emergency supply chains

> My research lab is currently exploring means to mass produce face shields and face masks. However, we are experiencing difficulties with obtaining supplies such as filters, transparencies, and elastic bands quickly. Could you guys help us with locating reliable suppliers for these materials? Thanks a lot!
>
> OSMS Facebook, March 2020

Not just the network of makers was distributed; so were users. Small-batch demand is the bane of modern supply chains; mass manufacturers are uninterested in wasting their time fulfilling order volumes below a certain quantity, while makers making a few items lack the manufacturing capability and supply chain knowledge to scale up to larger batch sizes. The post above, tagged #Help Needed, received 28 comments– including two offers of shipping large quantities of face shield plastic, an example of one of thousands of similar posts that appeared on OSMS to offer or solicit supplies. The Citizen Maker Response survey reveals that 92% of responding non-hospital institutions (including nursing homes, schools, and essential businesses) could not meet the minimum order size of large manufacturers, so they turned to makers; a full 92.4% of respondents fulfilled requests with fewer than 150 units per order (Cavalcanti et al., 2021). For healthcare workers in rural America and in Native American reservations, a few thousand PPE donations by a local branch of OSMS were sometimes enough to last for weeks. One OSMS user posted in late 2020: "Was on a call with the North Alabama hospitals and they told us that the maker community is building enough stuff to meet their needs. Best. News. Ever." (OSMS Facebook 2020).

4.8. Improvisations in safety and liability prevention

> I would like to say to those who are criticizing, who suddenly became experts in polymers or say that without a CE mark you can't do anything– think what it is to be sick in bed with a respiratory crisis, and you have the breathing machine right next to the bed but you're unable to use it just because it does not have the CE mark. We are in an emergency; this is not a normal situation.
>
> – Cristian Fracassi, quoted in Dettori (2020); translated by authors

Medical products are subject to extensive legal liability restrictions. Depending on the country, donations avoid liability under "good Samaritan" laws. In the first few weeks of the pandemic professional materials and testing labs were overwhelmed. Neither for professional manufacturers nor volunteer DIY efforts were there any publicly available safety guidance (Cavalcanti et al., 2021). Collaborating directly with governments, a few Makers obtained national certifications (notably, the Prusa RC1 face shield), while many sold their uncertified

devices or "donated" uncertified PPE to healthcare facilities that would then "donate" money to the producers in return to cover materials' costs, to avoid legal liability restrictions (OSMS Facebook 2020).

A distributed actor network lacks a standard quality control. The US Food and Drug Administration (FDA) certifies *factories* for medical device production, not individual designs or bills of material. Medical professionals trust certified products and need equally to be able to trust network distributed manufacturers of products made slightly differently in every location. A crucial issue for OSMS was how to establish legitimacy founded on trust in the absence of FDA certification. Through their medical review process, OSMS provided a stamp of approval on *designs and materials*, rather than factories, promoting an alternative institutional legitimacy. The project thus organized through standard design. OSMS's library of medically verified patterns began with a makerspace collaboration in the Philippines, the Manila Protective Gear Sewing Club, that reverse-engineered an isolation gown in collaboration with the country's Vice President, providing full documentation to the community. OSMS succeeded in establishing a rapid pipeline and medically verifying designs, even where governments faltered.

4.9. Improvisations in material testing

> "I saw the NIOSH test and said oh hey, we can do that… so we just fired up our testing equipment and didn't ask any questions."
>
> – MIT Chemical engineering professor (quoted in Reynolds et al., 2021)

Before OSMS could certify the safety of some design, they needed to prove the materials involved were reliable, especially for N95 masks, which must eliminate at least 95% of airborne particles. At the beginning of the pandemic, just two labs in the entire U.S. were approved for N95 certification; by the end of March 2020, all had 6 week waiting times to ship products. Makers and university researchers, networked to discuss alternative materials, ranging from vacuum filters to shop towels to multiple layers of mask, through OSMS. Makers attempted to verify a wide variety of N95 equivalent fabrics for homemade and makerspace masks before they could be shared with hospitals. A biomedical engineer, a respirator researcher and OSMS collaborator founded the MakerMask network, providing a scientifically backed database reporting on virus filtering abilities of commercially available facemask materials and offered guidance on DIY analogue testing for fit and performance.

In lieu of official testing equipment to verify materials for production, makerspaces became creative with their collaborations. In Colorado, USA, one medical centre contacted the MakerLab makerspace with a request for Powered Air Purifying Respirators (PAPR) and matching hoods. MakerLab worked with the medical centre, using materials that were not FDA-approved, to design and prototype the PPE required within three days. The local Fire Department's biohazard and hazmat coordinator figured out how to test and approve the supplies for medical use (Cavalcanti et al., 2021). Similarly, Makerspace Artisan's Asylum in Somerville, Massachusetts, collaborated with local hospital staff to test the strength of different materials for disposable gowns, deciding on lawn fabric sourced from Home Depot (Sarah Miller, in Cavalcanti et al., 2021).

4.10. Improvisations in rogue procurement

Many healthcare administrators refused improvised PPEs, despite chronic supply shortages. Leading frontline workers consequently chose to participate informally with OSMS (OSMS Facebook; personal communication). Many hospitals worried about liability, while many refused to request aid for fear of bad press if it became known that they had run out of official PPE (OSMS Facebook). Several doctors and nurses joined the Facebook group to negotiate supplies and provide recommendations on behalf of their colleagues, sometimes against the official guidance of their own healthcare facilities. In Brazil, the Olabi makerspace network took direct supply chains to a higher level with a tracking system called ProtegeBR, a publicly available platform listing 108 public health offices throughout Brazil, providing contact information for each facility, in addition to listing contact information for over 250 maker initiatives nationwide. The network succeeded in providing over 1 million items to healthcare workers (OSMS 2021).

4.11. Improvisations in curation and priority-setting

> "OSMS' primary value add in the early pandemic was this moderated and curated discussion forum, IMO, and the library of 35 supply categories/200 open-source designs are the long tail of value add for this and future crises."
>
> – Gui Cavalcanti, personal communication

Prior 3D printing initiatives were known to lack practicality, from 3D printed prosthetics that melted when holding a hot cup, to wasteful attempts to 3D-print large buckets for use in emergency situations. An MIT engineering professor issued a public warning: "The use of 3D printed devices and PPE in this type of situation could generate situations wherein unnecessary risk is added to an already challenging situation. It is possible to find 'solutions' that look good on paper but are unproven with respect to practicable sanitization processes …This can lead to a false sense of security where risk has actually been amplified." (Culper et al., 2020). Nonetheless, discussions of production strategies around materials and production equipment dominated the early days of OSMS, along with deference to medical staff, the primary beneficiaries (Pineda et al., 2021). From these emerged iterative, collaborative design discussions which ensured efficient and safe production. The choice of Googledocs as the preferred medium for production-ready designs, allowed OSMS to share production-ready manufacturing guidelines, while also letting anyone with permissions to be able to edit that document at any time, whenever better ideas emerged.

4.12. Improvisations in design selection and rapid feedback

> "In early April of [2020] we saw peaks of 250–300 posts per day …. Those were primarily design revision/request for feedback type posts. Those led to makers selecting what designs to manufacture, and then spooling up for production."
>
> – Gui Cavalcanti, personal communication

Limited time for improvised solutions meant OSMS relied upon community decision-making to converge timeframes of product choice, prototyping, R&D, and dissemination. The most popular posts on the OSMS Facebook group (often receiving hundreds of comments and over 1000 likes/reactions) were design revisions and requests for feedback on PPE designs. These OSMS posts were the project mechanism for makers to select the best and most appropriate designs to manufacture, ramping up production.

OSMS began expansion in late March 2020 with experienced open-source engineers making a concerted effort to streamline submission and feedback processes to filter quality designs. In April 2020, the OSMS team circulated internal flowcharts to direct new enquiries through appropriate channels (translation requests/offers, new designs, feedback on existing designs, trustworthy manufacturers, etc). Engineers, designers, medical professionals, and amateur inventors discussed specific items and processes in dedicated channels. Many productive conversations on Facebook posts moved from hasty comment threads into Slack, private messages, emails, and even video/phone calls. The actor network was living, evolving and unbounded, as is shown in the comment thread below dealing with face shield designs, which resulted in several "forks" of slightly different products depending on end users' preferences.

A. DIY Face shields

Selection of critiques on a popular post (1000+ likes) sharing a laser-cut face shield design:

> Commenter 1: You should remove the circles. They only add time and would be easier to sterilize without them.
>
> Commenter 2: Can someone comment on the need to close gap between forehead and shield[?] I hear conflicting information about whether this is necessary, including the report that staff stretch hair bonnet over front of shield.
>
> Commenter 3: Some want closed top, some do not. It's about a 50/50 right now.
>
> – OSMS Facebook, March 2020

In hospital settings, face shields were used only infrequently pre-pandemic and ordered just-in-time, disrupted by the pandemic. In the void created, the Maker community went through many iterations before settling on a handful of trustworthy, easy-to-make designs that would protect healthcare workers. The prototype face shield combined a transparent plastic shield made from clear vinyl file folders, donated plastic sheeting from soda companies or other readily available materials with a flat, thick plastic headband that could be 3D printed, laser-cut, or even injection moulded, depending on available equipment and materials. A major medical manufacturer, Boston Scientific, collaborated with makerspace Something Labs to improvise 1 million face shields using the makerspace's original 3D printed design (Cavalcanti et al., 2021). Half of OSMS survey respondents reported producing face shields– for a total of 25 million face shields over the course of 8 months (ibid).

B. Ear savers

> [The plastic ear saver] is a thing that wasn't at all sexy. Someone from our medical team found it on Facebook with 5 likes, and said it was critical.
>
> – Gui Cavalcanti, personal communication

Among OSMS's most popular designs turned out to be a thin, flexible strip of plastic, an "ear-saver" that attached mask loops behind the heads of healthcare workers to stop the loops from chafing ears. In the words of a healthcare worker: "Wearing masks all day every day is causing ears to bleed" (OSMS Facebook). One of the inventors of the product, Nick Franklin, later took his 3D-printable model into mass production to sell on Amazon and credited the community with his success: "Working with OSMS provided the inspiration and feedback I needed to test, iterate, and eventually bring my Ear Saver design to Mass Production!" (OSMS Facebook). Other iterations included headbands with buttons for mask attachment, which then forked into a different design for Black people with natural hair, for whom wearing headbands was not so easy (OSMS Facebook, April 2020).

C. Mask sterilization boxes

> One message that I haven't heard that I think would be most impactful is: don't discard respirators. I think hospitals will be digging them out of the trash in the next couple weeks.
>
> – OSMS Slack, March 2020

Growing awareness of mask re-use led makers and universities, with medical workers worldwide, to collaborate innovating sterilization methods from UV chambers to heating in an InstaPot. Sears think, a makerspace at Case Western University and OSMS collaborator, improvised and then developed a desktop UV sterilization chamber licensed to a local manufacturer for production, while OSMS' curated database (OSMS Facebook) provided comprehensive guidance on DIY options.

D. Other supplies

The OSMS report lists additional novel medical devices created by the network, including non-invasive ventilation helmets providing COVID-19 patients with pressurized oxygen to replace ventilators, plastic ventilator splitters to allow multiple patients to use the same ventilator, as well as intubation boxes made of transparent acrylic or polycarbonate to protect healthcare workers while working with ventilated patients. OSMS-affiliated inventors also created facemasks with clear windows over the mouth for people who needed to read lips and DIY door openers to allow people to use their feet to open doors rather than risk touching infected doorknobs. Nurses in full PPE in children's wards asked for specific face shield designs familiar to children. The request led to a variety of superhero-themed and Disney headbands to put on top of face shields, as well as one mask decorated like Darth Vader. Photos of these face shields were among the most popular OSMS posts, inspiring worldwide adoption.

E. Repair parts

> Perhaps more of a game-changer than Makers building new medical equipment is the ability to repair.
>
> – OSMS Facebook post sharing iFixit's repair manual library, May 2020

The just-in-time production of repair parts characterizes distributed manufacturing and the Maker Movement (Wells and Nieuwenhuis, 2004). The pandemic provided opportunity to design, iterate and produce repair parts globally. Frequent maker-collaborator, iFixit, worked with over 200 librarians and archivists to archive and organize over 13,000 manuals for medical devices on their platform by mid-May 2020 (Wiens, 2020). While structure was being developed in actor networks it was not designed and imposed by any authority or organization but emerged from the network. Common problems with prior proprietary manufacturing were resolved. OSMS participants and fab labs worked specifically on developing repair parts for ventilators, sometimes in collaboration with iFixit's larger efforts.

5. Discussion

We were motivated to ask, "*during a disruptive crisis, how are viable solutions identified through improvisational search by an agile network of actors?*" The context was one in which both state and markets failed in the crisis the pandemic created. Investigating rapidly responded solutions to the crisis, we discovered a rich ecology of diverse actors improvising solutions and disseminating them through digital networks that flowed through OSMS as a nodal point, an agile project owner. Not only makers, designers and suppliers but also users of protective devices responded to the shortcomings of organization by both state and market. An improvisational, distributed, voluntary actor network of dis-aggregated actors emerged as an agile project in rapid response to the unfolding pandemic. Access to life-saving devices needed to be rapidly distributed as delay entailed deaths due to the non-availability of appropriate PPE.

Earlier studies of improvisation generally portray crises as situations in which an organization's managers respond imaginatively to an unexpected problem (Baker et al., 2003; Weick, 1993). OSMS, however, is not an organization premised on being a formal structure of unified actors; neither OSMS' vision nor mission statements mention 'organization.' Instead, OSMS' diverse ecosystem was sustained by a series of digital platforms acting as nodal points for a complex adaptive and heterogenous system, improvising in non-linear dynamic ways as a single project in response to a global crisis (Bogers et al., 2020).

Our study uncovered a distributed network of actors, organizing conjoined artifacts (production spaces, equipment, supplies, etc.) and digitally mediated practice. We uncovered actor networking that, using

distributed improvisations, proved capable of achieving the scale of mass manufacturing, leading to product choice, design, and production that was globally available. All of this was achieved through the most agile of projects, absent very largely of either commercial market or organizational hierarchy. Previous scholars (e.g., Cunha et al., 2016) distinguish improvisation from other types of non-improvisational, systemic innovation as well as random, unplanned actions. Organizational improvisation intentionally enacts an action without advance planning (Cunha et al., 2016); responding to a disruptive crisis, the OSMS project did this without prior organization, leadership or authority structures. Organizational boundaries were digitally side-stepped, enhancing capabilities for improvisation.

By embedding improvisation within the context of global challenges, our study contributes to the literature in unique ways that are significant.

First, our finding suggest that collective improvisation can occur through virtual *actor networks organized as a collaborative project.* The actor network was virtual, rapidly constituted, did not have leaders and followers and was collectively self-managed. The OSMS case extends Baker et al.'s (2003) insight that improvisation processes can enable entrepreneurial activity to be distributed through a geographically distributed actor network of volunteers designing new products. We found a distributed network of disaggregated actors, adding to O'Toole et al.'s (2020, p. 4) insights on the "convergence" of design and execution. We extend their insights by not only exploring "data on distinct action streams" but also showing how individually mediated senses of "purpose" (Clegg et al., 2021a), in response to an unexpected event, enrolled a myriad of organizations and people as actors in networks combined in a project.

Second, prior literature defines improvisation as a deliberate temporal and substantive convergence of design and execution producing novel action (Hmieleski and Corbett, 2008; Miner et al., 2001; Vera et al., 2016). Prior research has largely focused on organizationally 'bounded improvisation' (Moorman and Miner, 1998b), involving novel processes or products created within formal existing structures and organizations (Busenitz and Barney, 1997). The improvisations that we have discussed were organizationally unbounded and project focused. The sense of purpose, to protect healthcare workers from COVID-19, defined the project in its duality. It needed an assemblage of disaggregated fabricators working on legitimated designs that could be supplied locally to healthcare facilities situated all over the world to provide PPE precisely because existing supplier organizations, overwhelmed by the effects of the pandemic on demand, shipping and supply of workers, were unable to meet demand and schedules. The void was filled by purposeful and previously unconnected actors linking specifications posted on the OSMS site with improvisations flowing from and contributing to further postings and network formation in an organically evolving project. Without 'attention' (Jarzabkowski et al., 2012) being focused through nodal points such as OSMS, the network of actors could not have formed so rapidly and effectively. OSMS marshalled open sources of innovation globally, balancing between free-for-all comment threads and curated expert advice. COVID-19, as a deadly and hugely disruptive event, disrupted existing organizations. The impact on hospital and supplier medical organizations reliant on just-in-time supply chains had not been anticipated and planned for as a contingency. In the absence of the improvised innovation in the actor networks that we have addressed in this research report, the deaths and disruption of key clinical personnel and procedures would have been far greater had this rapid collaborative project linking design thinking and doing not existed.

Third, our investigation of disaggregated, distributed actor networks sharing a common purpose in the wake of the crisis highlights *the role digital technologies play in affording improvisation*, a topic of great significance for resilience projects enacted in the face of crisis and an absence of formally organized projects. The pervasiveness of digital technologies (Yoo et al., 2012) made enhanced distributed agency possible (Garud and Karnoe, 2005). Globally distributed actors across diverse domains were able to network using the Internet (Wellman et al., 2003), social media platforms (Karahanna et al., 2018; Majchrzak et al., 2013), and makerspaces through sharing digital files (Bouwma-Gearhart et al., 2021). Consequently, immediate societal challenges could be simultaneously addressed globally and locally by emergent actor networks (Majchrzak et al., 2012). In our investigation, we observed the emergence of contingent actor networks and facilities (e.g., MakerMask and ProtegeBR), improvising immediate responses to existing overwhelmed institutional infrastructure through ecosystem-driven innovation (Autio et al., 2018). Technologies such as OSMS's disparate yet interconnected digital platforms (e.g., Facebook, Slack, Get Us PPE) and artifacts (e.g., 3D printers, digital PPE design templates etc.) were connected to actors' purposes (Clegg et al., 2021a; Majchrzak et al., 2013; Nambisan, 2017; Yoo et al., 2012) in a rapid, agile, global, collaborative project.

The actor networking initially resembled a garbage can (Cohen et al., 1972, 2012) but the space being filled was virtual. Various problems and solutions that were digitally dumped aligned only if they were attended to by random actors purposefully searching. The existence of the digitally virtual garbage can was problematic for hospital administrators' public acknowledgments that there were shortages and necessities in PPE. Unsurprisingly, some administrators were thus reluctant to delve in the metaphorical garbage can; it was users more than administrators who were a vital source of inquiry. Products such as the ear saver were born out of connecting medical personnel's chafed ears with fabrications produced by 3-D printing, meeting through the digital node that OSMS created. Collective accomplishments, initially randomly aligned, created actor networks where none had previously existed, such as Get Us PPE. Practice, enabled by 3-D Printers and the Internet, shaped the social space of OSMS as a project platform shaping a thousand or more fabricators' projects across the globe, giving the assemblage its duality. Virtuality assumed material meaning as it became enmeshed with the goals of hitherto unrelated actors constituting an actor network through their successive improvisations.

6. Conclusion

6.1. Theoretical conclusions

The paper has made a significant contribution to the emerging field of socialized project leadership. Whyte et al. (2022) raised two important ethical questions through which socialized project leadership could be recognized. The first was to consider who, when and how innovated in project delivery and across project ecologies. Project OSMS was concerned to be both globally inclusive and empower legitimacy in responses. The second was how to involve and give power to associated groups. Project OSMS empowered anyone globally that sought to respond to the grand challenge and did all it could using the platform to empower them in doing so. Our investigation of multiple actors innovating protective devices during the COVID-19 crisis highlights how improvisational projects can involve disaggregated networks of suppliers, makers, designers and users whose mediation in virtual space is digitally afforded in a collaborative purposive project. Geographically distributed actor networks in many locales and domains, globally and simultaneously collaborated to invent and produce PPE as a rapid response to critical events. Decentralized actor networks, such as peer production communities, gained efficiencies from incorporating diverse actor specializations' deep domain knowledge applied to dissimilar local contexts.

Instead of imposing generic, top-down solutions, OSMS's global peer production community brought together experts ranging across medical specialists, engineers and materials scientists. These actors shared solutions and translated others' ideas to fit their ways of inscribing meaning and working in safety. Material rapidly produced by different technologies in many different places met local needs globally because of a virtual platform. Open-source networks demonstrated "small-

world" effects by combining the benefits of a small pool of contributors with the global scale of thousands of loosely connected initiatives. Small-world networks (Latora and Marchiori, 2001; Uzzi and Spiro, 2005) allowed for greater communication and more effective, parallel problem-solving by distributed actor networks. While we know that organizations can successfully improvise in response to unexpected problems, our exploration sheds new insights into how globally distributed improvisational actors can create purposive project networks that respond to a disruptive crisis, through using digital technology affordances across social media.

6.2. Practical conclusions

Outside of pandemics, for other mission-oriented global challenges, will actor network solutions result in similar purposive projects? The search for solutions in 2020 was desperate, fast and initially disorganized. Many other critical actants disrupting society have a materiality quite distinct from that of a virus. The virus was global and its effects on everyone it touched were, within a range of outcomes, similar. Other crises, such as bushfires, floods, wars, famines and pestilence have a very different form of materiality. For a start, they are place based not global. Secondly, they cannot be addressed through curated, improvised knowhow that is digital accessible. Digital knowhow will not retard a bushfire, flood, war, famine or pestilence although it might help in dealing with its aftermath by linking up those displaced with those that can offer aid, in the form of shelter, sanctuary and support. The generalizability of the specific project duality that we have discussed is not easily replicable, until another pandemic occurs for which we are less than prepared. COVID-19 was one crisis in which a rapidly emergent improvised project was necessary; it is certain that it will not be the last.

7. Limitations

Our exploration has several limitations. Since our study focuses on the search for solutions during a disruptive crisis, these findings may not be generalizable beyond the boundary conditions of the research. A crisis is a state of exception; in a state of exception normal projects are suspended, breached and questioned. It was precisely these conditions that made both the actor network and our research of it, significant as a project duality.

In the chaotic circumstances that prevailed during the rapid response to COVID-19 we may have missed critical factors. Nonetheless, ours is one of the first studies to explore the role of distributed improvisational actor network agency collaboratively and digitally organized as a project duality during a disruptive crisis. In terms of explicit limitations, we acknowledge, first, that the distributed and global nature of OSMS limited our methodological ability to describe the shape of the network as a whole and provide statistically representative examples of improvisations. We were dealing with a fluid, evolving, liquid network, one in which such statistical representation would be difficult to provide. Some of the most successful OSMS projects, while they derived their ideas from the Facebook group, proliferated offline with minimal connections to the online community. Accessing these projects was extremely difficult.

In conclusion, we expand the literature on improvisation beyond its organizational confines to a realm of digital projects as solutions to mission-oriented grand challenges that arise in states of exception, such as public health emergencies. Project management scholars need to research project responses in their duality where and when they arise to create resilient frameworks in situations in which normal project management planning is difficult, if not impossible. OSMS was a new kind of project, extremely resilience-building, in responding to the COVID-19 crisis, exemplifying 'socialized leadership' (Whyte et al., 2022). Whether it can be prefigurative of further projects responding to crisis by building resilience remains an open question, perhaps awaiting the next global public health crisis.

Declaration of competing interest

There are no interests to declare of any kind that compromise this research.

Data availability

The data is all drawn form the public domain with the exception of personal communications that we mention.

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