Agile software development and software practitioners' productivity amidst the COVID-19 pandemic: a narrative review

Bokolo Anthony Jnr
Department of Applied Data Science, Institute for Energy Technology, Halden, Norway and Department of Computer Science and Communication, Østfold University College, Halden, Norway

Received 27 May 2022
Revised 10 November 2022
4 February 2023
Accepted 6 March 2023

Abstract

Purpose – As the novel coronavirus 2019 (COVID-19) impacts the world, software practitioners are collaboratively working remotely from home. The pandemic has disrupted software practitioners' productivity forcing changes to agile methodology adopted by software practitioners in software organizations. Therefore, this study aims to provide implication on the issues and recommendations for improving software practitioners' productivity and also examine the impact of the COVID-19 pandemic on agile software development.

Design/methodology/approach – This paper adopts a narrative literature review to provide early assessment based on secondary data from the literature and available document reports from studies published from 2019 to 2022 to explore software practitioners' productivity and agile software development during the working from home directive amidst the COVID-19 pandemic. A total of 60 sources which met the inclusion criteria were used to provide preliminary evidence grounded on secondary data from the literature. Descriptive analysis was used to provide qualitative findings from the literature.

Findings – Findings from this study present the significance of working from home directive on agile software development and software practitioners' productivity. More importantly, findings from the secondary data shed light on software practitioners' productivity adopting agile software development amidst the COVID-19 pandemic. Additionally, the findings present virtual collaborative platforms used by software practitioners, technical and social barriers of agile software development during the pandemic and recommendations for remote agile software development.

Originality/value – This study explores the significance of working from home directive on software practitioners' productivity during COVID-19 pandemic and further investigates how are software practitioners' productivity adopting agile software development practices amidst the COVID-19 pandemic. Besides, this study discusses the challenges software practitioners currently face and offers some strategies to bridge the gaps in agile software development to help software practitioners, system developers, software managers and software organizations adapt to the changes caused by the pandemic.

Keywords Software organizations, Agile software development, Software practitioners' productivity, Work from home, Virtual collaborative platforms, COVID-19 pandemic

Paper type Literature review

1. Introduction

As at May 2020, the coronavirus 2019 (COVID-19) had spread across the world, government officials and public health strongly suggested or mandated that residents practice social distancing (Borowski, 2020b; Jnr, 2020). In June 2020, most countries had reached the peak of COVID-19 infections, but a few countries still practiced work from home (WFH) or remote

Journal of Science and Technology Policy Management
© Emerald Publishing Limited
2053-4620
DOI 10.1108/JSTPM-05-2022-0093

workplace directives (Adams and Walls, 2020; Jnr, 2020). Accordingly, the COVID-19 did force most industrial sectors to change their mode of working to remote workspace (Xaverius, 2020; Butt *et al.*, 2021). As such, enterprises such as software-based organizations continued to provide support to software practitioners' safety while ensuring that their organization continue to function in a physical or virtual working environment (Blueoptima, 2020b). Accordingly, software organizations are deploying flexible strategies that will facilitate remote work functionality for software practitioners to sustain both physical and mostly virtual working practice (Da Camara *et al.*, 2020; Slabe-Erker and Primc, 2021). Hence, software practitioners are adapting to digital working policies and are also required to maintain productivity during and after the pandemic (Blueoptima, 2020b; Mancl and Fraser, 2020).

Evidently, software organizations were also impacted by the pandemic due to its deeply interconnected market to global information technology and Web applications used in other sectors, such as electronic commerce, education, banking, health care and supply chain (Nagar, 2020). As such, the pandemic did prompt businesses to use customer-based software, resulting in needed changes to software engineering methods and cultures (Shaheen, 2020). Thus, the nature of software development was changed to accommodate new requirements needed to sustain other sectors that depended on new innovative applications due to digital transformation (Anthony Jnr and Abbas Petersen, 2021). As 2020 unfolds, more businesses are using software to engage with their clients directly, allowing them to make orders, request services and more (Shaheen, 2020). But, presently, during and after the COVID-19 public health emergency, it is challenging for software organizations to get any new product launch unless the software product has an explicit role in supporting other businesses cope with the pandemic (Kobielus, 2020). Consequently, this has resulted to a shift toward customer-oriented software paradigm, causing a change to software development methodologies to cater for customer-based software products (Kobielus, 2020).

Respectively, agile software development is currently the common software methodology adopted by software practitioners to provide principles and values for developing working software platforms rapidly while responding efficiently to changes caused by the pandemic (Lindsjørn *et al.*, 2021; Neumann and Bogdanov, 2022). This is because agile software development is better adapted to be flexible for software practitioners during and now after the pandemic to provide customer-based software products (Blueoptima, 2020b; Russo *et al.*, 2021). In response to software practitioners' productivity in the context of COVID-19, findings from the literature (Lindsjørn *et al.*, 2021) reveal that amidst the pandemic that teamwork among software practitioners worked well despite them working remotely. Though many staff's inspiration declined just after the lockdown, their enthusiasm increased as remote workspace was provided when they use collaborative virtual tools to work digitally collectively as a team (Lindsjørn *et al.*, 2021; Sathe and Panse, 2023). Furthermore, Sathe and Panse (2023) maintained that by adopting an agile mindset, software development teams are better at responding to public crisis, ultimately improving productivity. On the other end, researchers such as Nagar (2020) advocated for designing and adapting agile methodology during the pandemic and beyond for end-user-centric software, focusing on market requirements and analysis in creating a vision and roadmap.

Presently, there are fewer studies that have explored how agile methodology is being adopted by software practitioners during the COVID-19 pandemic. Hence, there is a need to explore the issues and also provide recommendations to software practitioners on how to maintain productivity during remote agile software development in response to the working from home directives (Bao *et al.*, 2020; Elavarasan and Pugazhendhi, 2020;

Lakshmi Priyadarsini and Suresh, 2020; Ralph *et al.*, 2020). Therefore, the main objective of this study is to explore the significance of working from home directive on agile software development during the COVID-19 pandemic. Second, this study contributes to the recently emerging literature by examining software practitioners' productivity in adopting agile software development amidst the COVID-19 pandemic. In addition, this study identifies the virtual collaborative platforms adopted by software practitioners during WFH amidst the COVID-19 pandemic. Finally, this article presents issues and recommendations for improving productivity of agile software development during and after the COVID-19 pandemic. The rest of the article proceeds as follows: Section 2 outlines the methodology. Section 3 presents the findings. Section 4 reports the discussion and implications. Section 5 is threats to validity, and Section 6 is conclusion, limitations and future works.

2. Methodology

The World Health Organization (WHO) advocates that academic reviews are important in providing informative findings of issues during the pandemic (Brown *et al.*, 2020). This current study, therefore, aimed to undertake early assessment review of secondary sources to explore software practitioners' productivity during agile software development amidst the pandemic. To conduct this review study, a review protocol was developed on the basis of the standard review, similar to prior studies (Bokolo, 2020; Brown *et al.*, 2020; Jnr, 2020). Figure 1 depicts the review protocol of this study.

The used research review protocol includes four main activities: specification of research questions, deployment of search strategies, study selection strategies (inclusion and exclusion criteria and quality assessment criteria [QAC]), and finally, reporting of findings by synthesizing and extracting evidence from the selected sources. The following subsections describe the specified activities that were conducted to provide evidence for this study.

2.1 Research questions

While prior studies have examined working remotely in software engineering, only a fewer studies have explored working from home during a pandemic or disasters (Ralph *et al.*, 2020). Therefore, software organizations have limited evidence on how to support software practitioners to improve productivity during and beyond the current pandemic, which raises the following research question:

RQ1. What is the effect of social distancing and remote software development during COVID-19 pandemic?

RQ2. How are software practitioners' productivity impacted amidst the COVID-19 pandemic?

RQ3. What virtual collaborative platforms were adopted during work from home amidst the COVID-19 pandemic?

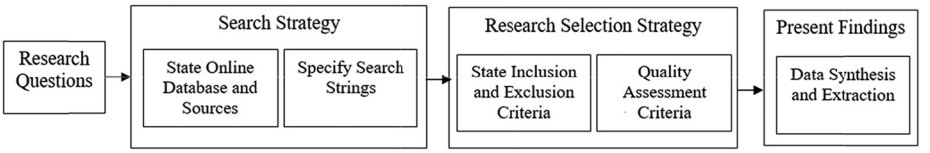

Figure 1.
Review protocol

RQ4. What are the issues and recommendations for improving productivity of software practitioners during COVID-19 pandemic?

2.2 Search process strategy

2.2.1 Resources. To extensively search for related studies, the search strategy began with an online search from digital libraries. Prior studies related to this current study were extracted from electronic database resources, namely, Google Scholar, PubMed, Medline, ScienceDirect, ProQuest, Springer, Wiley, IEEE Xplore, ACM, Emerald, Taylor and Francis, ISI Web of Science, Sage, Inderscience and Scopus (Bokolo, 2020). These digital databases/libraries were selected because they are considered appropriate search engines for reviewing software engineering and health informatics. Moreover, they provide options of conducting advanced search by field and keywords and categorize retrieved results by research domain, type and year. Using keywords, the corresponding author specified search terms or keywords in performing online searches of digital databases/libraries. To ensure the quality of the review, search terms were mainly formulated on the basis of the specified research questions (see Section 2.1). Also, data was collected from Web sources as the discussion on COVID-19 and software development is still emerging, and it was appropriate to search for evidence from online sources and document reports published on websites.

2.2.2 Search strings. In conducting the search from digital databases/libraries and websites, search strings were formulated with Boolean operators (AND, OR) to improve the searching of secondary sources and to increase the quality of the search process. Thus, the search strings were formulated based on the title, abstract and keyword of the current paper. The main search terms comprise software engineering OR software development OR software practitioners OR software developer OR software practitioners OR software organizations AND (coronavirus 2019 OR coronavirus 2019-pandemic), COVID-19 OR coronavirus 2019-pandemic AND (productivity OR agile) AND (impact OR effect). The search was carried out in 2020 and later in 2022 to include literature, as newer studies were published related to the study area in 2022.

2.3 Research selection strategy

Research selection strategy is used to assess whether or not the retrieved secondary sources in the initial stage of the search process have to be included to provide answers for the research questions (see Section 2.1). In this study, the research selection strategy is used based on the inclusion and exclusion criteria and QAC. A total of 53 studies were retrieved during the initial search process form the digital libraries. Thus, scrutiny was important to identify the most appropriate studies related to COVID-19 pandemic and software engineering. Figure 2 depicts the preferred reporting items for systematic reviews and meta-analysis (PRISMA) used in this study, similar to prior studies for selection process (Brown *et al.*, 2020; Jnr, 2020).

Thus, as seen in Figure 2, 53 studies were retrieved from digital libraries, and another 13 sources were included from website and document reports published online, totaling 66 sources. However, no duplicates were excluded. Four sources were removed due to titles and abstracts not related to the research questions. Next, the selected studies were assessed based on inclusion, exclusion and QAC, and 24 sources were excluded. No new sources related to the research domain were included via cross-referencing. Thus, a total of 38 sources were initially selected. Then in 2022, 22 new peer reviewed articles indexed in Scopus and/or Web of Science were included. This resulted in a total of 60 sources (as seen in Figure 2) used to provide secondary data to proceed with the study.

2.3.1 Inclusion and exclusion criteria. Inclusion and exclusion criteria were designed based on the research questions. First, the title and abstract of the retrieved journals and

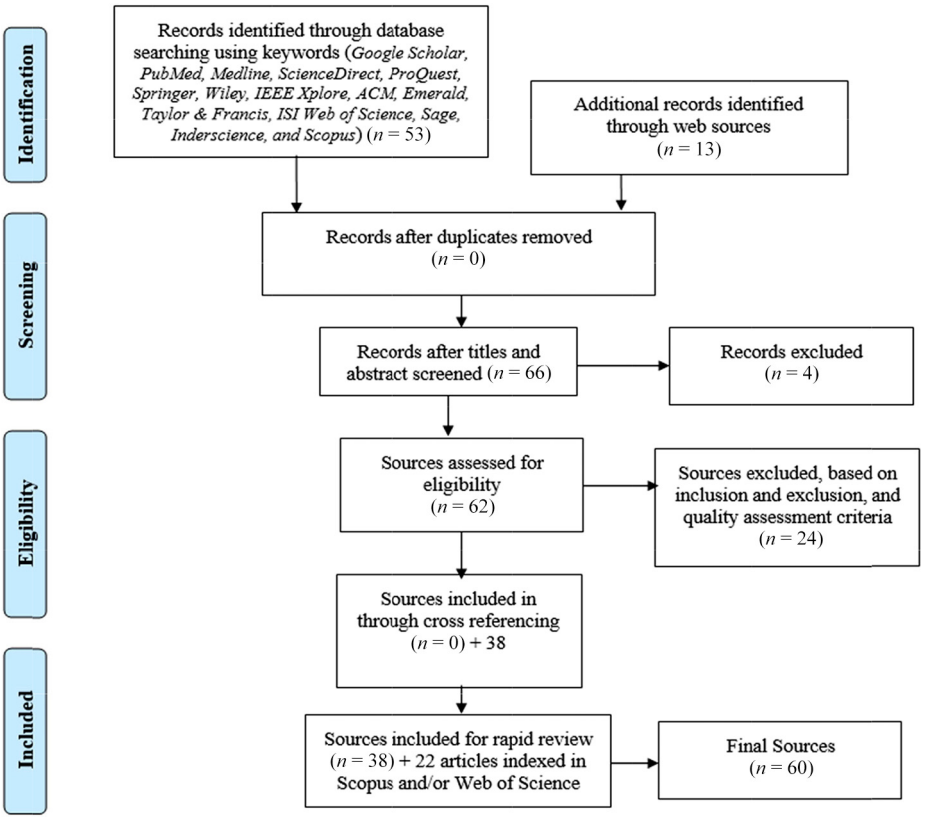

Figure 2.
PRISMA flowchart for the study selection process

conference proceeding papers were carefully examined. Next, papers that were not related to COVID-19 pandemic, agile software development and not able to provide evidence for the formulated research questions were excluded. In the case of duplicates of the same source, such as preprints and final version, the recent version of the article was included only. The studies included in this research were published between 2019 and June 2022 (studies on COVID-19). In addition, all sources written in languages other than English were excluded.

2.3.2 Quality assessment criteria. The QAC is considered one of the most important phases in the research selection strategy as it aims to assess the quality of selected sources. Since this study is exploring an emerging societal issue in agile software development theory and practice, the assessment of the selected sources is performed based on the content of the included papers in relation to the specified research questions that are related to the research domain. The QAC was applied by precisely evaluating the content of the title, abstracts and contents of all selected 60 sources. In addition, the corresponding author ensures that more than 50% of the included articles are indexed in Scopus or Web of Science databases.

2.4 Data extraction and synthesis

This stage of the study aims to synthesize and extract evidence from the included sources as related to the COVID-19 and agile software development productivity of software

practitioners amidst the pandemic. Thus, the selected studies were studied in detail, and appropriate data were extracted to provide descriptive analysis in response to the research questions (see Section 2.1), similar to a prior study (Jnr, 2020).

3. Findings (descriptive analysis)

3.1 Secondary sources distribution

The 60 sources included in this study are seen in Figure 3. These 60 studies are selected as they are aligned with the scope of this study. Overall, the 60 sources comprise the following: (n = 29, 48%) for peer-reviewed journal articles, (n = 13, 22%) for document report and online sources, (n = 6, 10%) for preprint research papers and (n = 12, 20%) for research papers presented and published in a conference proceeding.

Figure 3 shows the distribution of secondary sources used in this study. The reference to each study is presented in the reference section of the paper. The findings, as seen in Figure 3, suggest that there are more journal studies (29 peer reviewed articles) published that explored the relationship between agile software development and software practitioners' productivity during the COVID-19 pandemic. Although only few of these studies are grounded on secondary data. This necessitates the need for a study based on the review of existing literature.

3.2 Effect of social distancing and remote software development during coronavirus 2019 pandemic

3.2.1 Impact of coronavirus 2019 in software organizations. The coronavirus 2019, which is also referred to as a severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), spread

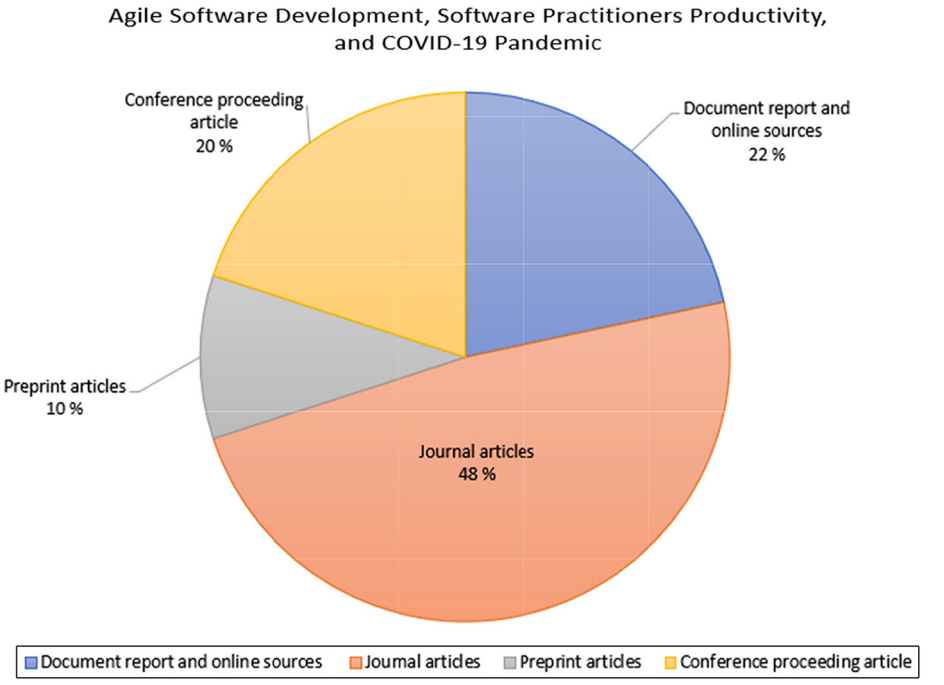

Figure 3.
Distribution of selected sources on COVID-19, agile software development and software practitioners' productivity

across the world with more than 9,000,000 confirmed cases and more than 400,000 deaths as reported in June 2020 by the Johns Hopkins University COVID-19 dashboard system (JHU, 2020). Since the WHO declared the COVID-19 a pandemic in March 2020, several countries have initiated new regulations limiting the movement of their residents and the temporal closure of nonessential businesses (Williams and Kayaoglu, 2020). The COVID-19 pandemic has resulted in several countries being in indefinite lockdown mode resulting in individuals in different sectors working from home, or other simply not working (Nagar, 2020; Shaheen, 2020). This has had a significant effect on organizations and staff in mostly service-based industries such as entertainment and hospitality (Williams and Kayaoglu, 2020). Although the overall impact of the pandemic was perceived to be generally negative across several service organizations and the wider economy, this may not be universally the case for all organizations.

One notable exception is the software-based sector, where software practitioners continue to work remotely or digitally via collaborative platforms as demand for software is growing due to the pandemic (Nagar, 2020). Findings presented by Fernandes (2020) indicated that 75% of organizations report disruptions in their productivity; as such, the lead times for many US organizations doubled (Fernandes, 2020). On the contrary, findings from other sources confirmed that the functioning of global software development was disrupted by the public health crisis (Bao *et al.*, 2020; Blueoptima, 2020b; Spurk and Straub, 2020). The disruption to software development resulted in an increase in the cost of business for software companies (Blueoptima, 2020b). Accordingly, the software sector is one of the areas in which the COVID-19 has impacted (Nagar, 2020; Shaheen, 2020). The software development sector is similar to the online sales and service sectors, which prior to the public health crises accounted for at most 10% sales, but has observed substantial growth in terms of job opportunities, sales and revenue (Williams and Kayaoglu, 2020).

3.2.2 Social distancing and remote agile software development. Social distancing is one of the nonpharmaceutical countermeasures used to reduce physical contact between persons, thereby lessening the possibility of new infections (Brown *et al.*, 2020; Jnr, 2020). To comprehensively implement social distancing measures to effectively slow the spread of the virus, working from home was also adopted by software organizations (Elavarasan and Pugazhendhi, 2020; Lakshmi Priyadarsini and Suresh, 2020). This current practice has provided software organizations with the question of exploring if working from home is as productive as compared to working physically in the organization's premises (Kramer and Kramer, 2020). Furthermore, one of the most apparent changes which occurred due to the COVID-19 pandemic has been many practitioners working from home across different sector during 2020–2021 (Kramer and Kramer, 2020).

Accordingly, Google, Apple and Microsoft instructed their employees to WFH. An example is Twitter Inc. which recently mentioned that some staff can continue working from home permanently (Ralph *et al.*, 2020). This is consistent with reports from Nagar (2020) which mentioned that Twitter urged 5,000 employees in Japan, South Korea and Hongkong to WFH. This is plausible as software developers can perform their day-to-day tasks (for example, build projects, writing code, debugging and reviewing code) as usual by digitally accessing resources of the organization when working from home (Ralph *et al.*, 2020; Spurk and Straub, 2020). Indeed, many software managers are already planning to move at least 5% of previously on-site staff to permanently remote positions as post-COVID-19 strategy (Ralph *et al.*, 2020). Although, a few software managers believe WFH might have different impacts on software development productivity, which is a great concern of software organizations (Bao *et al.*, 2020; Marek *et al.*, 2021).

Findings from Ralph *et al.* (2020) reported that working from home is often claimed to increase productivity, and teleworkers constantly confirm increased perceived productivity while working remotely (Ralph *et al.*, 2020). Additionally, findings from the literature suggest that software practitioners who previously worked remotely are 24% more successful to be productive working remotely as compared to those who do not have prior remote working experience (Bao *et al.*, 2020). On the contrary, software practitioners working from home might have a negative effect on productivity as it may destabilize communication among software practitioners, which is important during agile software development (Bao *et al.*, 2020).

3.3 Impact of software practitioners' productivity amidst the coronavirus 2019 pandemic

3.3.1 Agile software development and coronavirus 2019 pandemic. Since the inception of the agile manifesto in 2001, agile software methodology has transformed software development practice by strongly emphasizing active end-user involvement, evolutionary delivery and change tolerance (Aldave *et al.*, 2019; Ågren *et al.*, 2022). Therefore, agile approaches are mostly dependent on close collaboration and communication to be productive at delivering value irrespective of the location of team members (Nazir *et al.*, 2022). The given nature of agile software development possesses the ability to rapidly adapt swiftly and anticipate change to provide productive results during the software development life cycle (Blueoptima, 2020b). Agile approaches are open to continuous modification of system requirements, as it mostly rely on loosely structured user requirements. Thus, agile approaches create discussions between the software developers and customers (Batra, 2020; Griffin, 2021).

However, agile approaches have been criticized for less focus on architecture (Kropp *et al.*, 2020) and for being more suitable for smaller project teams since it requires coordination and management effort (Malgonde and Chari, 2019). In agile approaches, it is assumed that information systems can be developed through continuous design, iterations, improvement and testing grounded on rapid feedback and change (Aldave *et al.*, 2019; Marinho *et al.*, 2021). Agile approaches are end user-centric and considers the value that clients bring to software development. Hence, an important characteristic in any agile approach is the close and continual collaboration between software practitioners and clients (Aldave *et al.*, 2019). Therefore, agile approaches are mostly dependent on the on-site customer identifying and prioritizing requirements, providing feedback and suggesting change in the course of the software product development (Batra, 2020; Neumann *et al.*, 2022).

3.3.2 Productivity in software organizations amidst the coronavirus 2019 pandemic. Productivity is the amount or measure of work accomplished over a period. In software development, current productivity measurement, such as counting the number of modified lines of code (LOC) or the number of commits in a certain period, is not effective as such has been critique as being low in construct validity (Bao *et al.*, 2020). This is because the number of commits does not necessarily correlate with quality or size (Jnr, 2019) in relation to derived value. Similarly, some software developers and system engineers might prefer to use complex one-line solutions, while others may like to present their code in several lines (Ralph *et al.*, 2020). Thus, productivity in software development is often assessed by software artifacts or products developed by the software developers in a set time (Topp *et al.*, 2022). Hence, productivity can be measured based on certain criteria, for example, checking function points (Sathe and Panse, 2023), submitted LOC and completed tasks in relation to the time taken to implement the assigned requirement (Bao *et al.*, 2020).

But the COVID-19 pandemic may have a negative impact on software developers' productivity. As people are likely to be more distracted by fear of the uncertainty, lower motivation, which, in turn, impacts the productivity and commitment of software practitioners working remotely from home (Ralph *et al.*, 2020; Kettunen *et al.*, 2021). Thus, COVID-19 has affected the society, inadvertently affecting software organizations. Lockdowns and WFH directive have led to a disruption in the software development process (Nicola *et al.*, 2020). Accordingly, agile software development approaches were believed to be adopted in small, colocated project teams (Batra, 2020). But, over the years, the success in small project teams has inspired agile approaches in large software development, which comprises teams working remotely (Aldave *et al.*, 2019; Schmidt and Gutfreund, 2022). Hence, it is important to explore the correlation of COVID-19 and agile software approaches. Thus, this current study explores the productivity of software practitioners when working from home amidst the COVID-19 pandemic.

The pandemic has made software development to be more relevant, given the fact that the society exclusively depends on digital technologies (Neumann and Bogdanov, 2022). The COVID-19 disruption has impacted the software development process and agile collaboration (Kude, 2020). Although researchers such as Kobielus (2020) have argued that the COVID-19 pandemic has not really affected software practitioners, suggesting that COVID-19 may be the tipping point in creating a new norm for software development practices. As physical distancing saves software programmers time from several meetings and can help them to be more effective in multitasking (Kobielus, 2020). Practically, software programming team members hardly need to be in a physical office as long as they can write, deploy and test the codes remotely in a DevOps pipeline (Kramer and Kramer, 2020). However, programming is a creative process that may require face-to-face conversations and meetings among software programmers (Kobielus, 2020). Therefore, the COVID-19 pandemic has resulted in changes in software organizations based on the identified factors discussed below:

- Global hardware supplies are postponed.

Most software technology firms in the world are dependent on hardware components. But during the pandemic, many factories, especially the computer hardware units, were operated on limited operational capability (human resources). A few had to postpone production and temporarily closed their departments (Nagar, 2020). This then resulted in a shortage of hardware materials and delay in the delivery of ordered hardware. Based on the research by Chinese market research organizations, COVID-19 was likely to make a negative impact of 10.4% loss of smartphone shipping, 12.63% reduction in notebooks and 10.1% decline in video game consoles caused by a reduction in hardware production in 2020, impacting software industry (Nagar, 2020):

- Postponing of software consultations.

The pandemic then resulted to sudden cancellation of the workshops and exhibitions in the software development service industry by tech giants around the globe (Nagar, 2020). The industry leader Apple postponed the date of Apple's worldwide developer conference. Microsoft, the industry pioneer, also then postponed its software developer's consortium, which allows the software developers to meet and share the latest technologies (Nagar, 2020; Ganji and Parimi, 2021):

- Increase in unemployment.

Due to the COVID-19, it is possible that software organizations will now change from native application development to progressive Web application development for cost reduction

may lead to job reduction (Rawcliffe, 2020). A recent survey indicates that 53.8% of software practitioners are concerned about their jobs (Nagar, 2020). Although findings from Borowski (2020a) indicated that the ratio of software developers reporting finding a job declined in April 2020, even while those registering to prepare for interviews increased in April 2020:

- Affecting health and wellness.

Software practitioners and system engineer, like everyone in the society, were dealing with the pandemic using technology (Skelton, 2020). Findings from Borowski (2020a) reported that 75% of software practitioners and system engineer are concerned about their mental and physical health. Software practitioners' well-being while working digitally is influenced by their emotional stability when stressed. Working remotely may increase high emotional stability and autonomy, hence improving software practitioners' well-being (Ralph *et al.*, 2020). Conversely, working remotely can exacerbate psychological, social and physical strain on staff with low emotional stability (Ralph *et al.*, 2020). As such, findings from a recent study, Ralph *et al.* (2020) revealed that the best way to improve productivity is to support software practitioners maintain their emotional well-being. Moreover, software practitioners, like other working-class practitioners, use private vehicles for mobility needs, which emits CO_2 to the atmosphere (Ope Olabiwonnu *et al.*, 2022); thus, working from home also reduce CO_2 emissions:

- Increased usage of virtual collaborative platforms.

For most software practitioners and system engineer, virtual collaboration will be the primary fallback tool until normality returns (Kobielus, 2020). Findings from Borowski (2020b) revealed that 43% of software developers are currently adopting virtual technologies to support remote work. Thus, virtual technologies that support software development can range from whiteboarding and document sharing during the planning and requirement phase (Anthony Jnr, 2021a; Anthony Jnr, 2021b). Also, synchronous and asynchronous communication applications such as CodeSandbox, Cisco Webex Teams, Microsoft Teams, Zoom, Codeshare, Microsoft's Visual Studio Live Share, Floobits, AWS Cloud9, Slack, Git repositories, Codeanywhere and Teletype were used (Shaheen, 2020; Kobielus, 2020).

Available add-on or Web-based services can be integrated to existing editors to enable real-time collaboration and sharing of coding projects. Such tools enable software practitioners and system engineer to share project environments with various team members (Kobielus, 2020). Software developers can manage files together in real time, edit codes in active tabs and switch files. These collaborative platforms offer text and/or video chat panel inside the development environment (Xaverius, 2020; Bokolo, 2021) to help maintain productivity (Blueoptima, 2020b; Pinkus, 2020).

3.4 Virtual collaborative platforms adopted during work from home

Virtual collaborative platforms were adopted during the COVID-19 pandemic by software developers for agile software development. As previously stated, synchronous and asynchronous communication applications (virtual collaborative platforms) were being used by software developers for agile software development during the COVID-19 pandemic, as mentioned in the literatures (Nagar, 2020; Pinkus, 2020; Rawcliffe, 2020; Shaheen, 2020; Skelton, 2020). A few of these platforms are discussed below:

- CodeSandbox.

CodeSandbox is a Web-based editor that supports rapid Web development. It helps software developers to quickly deploy prototypes; as such, it is suitable to be adopted by

software developers during the pandemic, as it aids easily experiment and sharing of prototypes via links created with a click feature. Besides, CodeSandbox can be used to create full-stack Web applications, apps for Web browser and static sites. It reduces complexity and facilitates productivity of agile development. During agile development CodeSandbox simplifies collaboration by connecting software developers and system developers to code together:

- Cisco Webex Teams.

Cisco Webex Teams is a collaboration platform that offers a secure virtual workspace. It provides a user-friendly interface that connects software development teamwork members working on the same project remotely. It helps to support third-party app integration and simplifies daily interactions via a digital whiteboard. Cisco Webex Teams also ensures file sharing and messaging to ensure a seamless workflow within agile software development:

- Microsoft Teams.

Microsoft Teams is a patented business communication application developed by Microsoft. It offers workspace chat, file storage, messaging, videoconferencing, etc., among group involved in a project. It provides application integration and has been used as a virtual environment for agile software development. Microsoft Teams is being used by software developers mostly due to the COVID-19 pandemic:

- Zoom.

Zoom is a video telephony trademarked platform owned by Zoom Video Communications. It offers a free plan which offers video chatting service that supports up to several users; as such, it is used in agile software development. Software developers and system engineers can use Zoom, as it has the option to support up to 1,000 project team members for remote work and virtual meetings lasting up to 30 h, amidst the COVID-19 pandemic:

- Codeshare.

Codeshare is a platform that supports real time communication and code collaboration. It aids software developers to share code during agile software development, as it facilitates troubleshooting issues and pair-programming. Codeshare also can be used to facilitate collaboration and conducting of interviews:

- Microsoft's Visual Studio Live Share.

Microsoft's Visual Studio Live Share is a tool developed by Microsoft to support real-time collaborative code editing in the Visual Studio Code editor and Visual Studio integrated development environment (IDE). It supports software developers to view same code without configuring the same development environment, tools or settings using a collaborative session. Thus, software developers can work together to debug code using Microsoft's Visual Studio Live Share code's debugging console functionalities:

- Floobits.

Floobits is a new platform that allows two software developers to write code simultaneously on the same codebase, referred to as pair programming. Using Floobits plug-ins software developer can pair program directly within the same text editors as Floobits via an integrated Web-based editor who provides access to Google Hangouts enabling text chat, audio and video conferencing:

- AWS Cloud9.

AWS Cloud9 is a cloud-based seamless IDE that supports software developers to write, run, test and debug their code via an online browser. It comprises code editor, terminal and debugger. Cloud9 supports several programming languages, such as Python, JavaScript and Hypertext Preprocessor (PHP). Software developers use AWS Cloud9 to easily define code resources, debug and change between remote and local execution of their prototypes. In deploying Cloud9 in agile software development, software developers do not need to install or configure their development machine to use Cloud9. In addition, AWS Cloud9 aids pair programming and tracking of project team members inputs in real time and is used by software developers during the pandemic:

- Slack.

Slack is a platform that offers channel-based messaging, supporting software developers to effectively work virtually. It provides Internet Relay Chat functionalities such as the chat rooms or channels systematized by direct messaging, topic and private groups. Slack aids the creation of teams, supports messaging, facilitates integrations with other third-party applications and provides Application Programming Interface for software developers to develop applications and autonomous seamless processes required in agile software development process:

- Git Repositories.

Git is an open source and free system designed to manage software development projects with fast performance and productivity. Git supports data integrity and is mostly easy to learn, with features such as enabling the tracking of changes in any set of files. It is typically used by software developers and system engineers for collaboratively managing software source code during agile software development:

- Codeanywhere.

Codeanywhere is a cloud-based IDE which enables software developers to rapidly write, edit, debug, run and test Web development prototypes via a Web browser and mobile devices. It supports collaboration among software developers to deploy code in DevBoxes or via their own virtual machine using Secure Shell Protocol or File Transport Protocol (FTP) protocol. Besides, it integrates and connects to other platforms such as Google Drive and Dropbox. It also supports several programming languages such as HyperText Markup Language, Go, PHP, Ruby JavaScript, Node.js and Python:

- Teletype.

Teletype is an enterprise-based instant messaging and Web conferencing application which supports seamless collaboration and communication for software development team. Teletype offers a reliable, secure and workspace to share information during agile software development, promoting collaboration among software developers and system engineers. Teletype also provides feature for full management, data storage, theme control and improved security.

Furthermore, based on the reviewed virtual applications, Table 1 depicts advantages and disadvantages of the virtual applications used by software developers for agile software development and system engineering during the COVID-19 pandemic.

Table 1. Advantages and disadvantages of virtual applications used by software developers

Virtual applications	Advantages	Disadvantages
CodeSandbox	• Open source • Supports fast Web development • Provides a seamless development environment to build software projects	• Limited video guide for software developers • Limited integration into external systems
Cisco Webex Teams	• Can be used on several devices • Support collaboration • Integrates into other applications	• License fee is required
Microsoft Teams	• Easy to setup and use • Increased project team productivity • Also secured as it uses two-factor authentication and files are stored in SharePoint encryption	• Offer limited flexibility to users
Zoom	• Easy to install and use with better video quality • Light weight application and supports recording	• Has different subscriptions • Has many add-ons
Codeshare	• Support real time software development • Suitable to be used when interviewing a software developer	• Has different subscriptions
Microsoft's Visual Studio Live Share	• Supports collaborative code debugging and testing	• The user must have Microsoft's Visual Studio in their system first
Floobits	• It helps to remotely connect software developers and system engineer teams	• Requires Google Hangouts to enable text chat, audio and video conferencing
AWS Cloud9	• Support the quick sharing of codes with team members	• Setup is not quite easy • As the project increases, the speed of the editor usually slows
Slack	• Supports several platforms • Compatible with numerous types of services, applications and frameworks	• Limited file storage as such files are sent as e-mail
Git repositories	• Helps to manage agile software development projects with speed and efficiency	• Mostly requires knowledge of technical skill • The GUI is quite poor • Lacks support for window users
Codeanywhere	• Offers a software development system that enables the management of files from remote services and supports the collaboration, embedding and dissemination of codes	• Integrates mainly with FTP, Dropbox and GitHub
Teletype	• Uses end-to-end data encryption • Offers remote control for file management	• Has different subscriptions

3.5 Issues and recommendations for improving productivity of agile software development during coronavirus 2019 pandemic

3.5.1 Technical and social barriers of agile software development during the pandemic. Contemporary agile software development strives to be lean and adaptive. This has certain benefits in normal times but may be less satisfactory in a remote situation as agile approach involves more collaboration among software practitioners. One of the main tenets of agile software development is its emphasis on iterative and collaborative work as team members meet regularly as prescribed by methods such as Extreme Programming or Scrum adaptive (Kude, 2020). For instance, in agile approach, software programming team members jointly develop code, ensuring quality control. The iterative and collaborative approach of agile development also extends to end-users and clients who are frequently involved in the software development phases early on and on a continuous basis. But, during the COVID-19 pandemic, client`s feedback may not be readily available, and this may lead to delays (Kude, 2020). Furthermore, software practitioners are faced with ergonomics challenges which refer to the degree to which an environment is conducive, comfortable and safe to work. Software practitioners with more ergonomic home offices are more productive.

Likewise, Ralph *et al.* (2020) mentioned that the availability of a dedicated workspace at home and the availability of organizational resources can increase software practitioners' productivity. Additionally, the phase of the project might affect software practitioners' productivity. Findings from Bao *et al.* (2020) argued that software developers at the end of the projects understand activities than those of projects in the start stage. Thus, different project phases have an impact on the productivity of software practitioners when working from home (Bao *et al.*, 2020). In addition, different project sizes, which are measured based on the number of software practitioners involved in the project, might have an impact on productivity. Due to the project size, the project may be managed differently, which will impact software development. For instance, it might be more challenging to communicate with team members in a large project when working remotely, which might decrease productivity of the project (Bao *et al.*, 2020).

3.5.2 Recommendations for remote agile software development. A remote agile software development approach can ease collaboration and add flexibility, which can contribute to a productive working environment. Agile approaches, such as Scrum, can be adopted for planning, as software practitioners work in small iterations referred to as sprints for continuous improvement that can foster software team productivity. The development of agile processes is mostly leveraged on proactivity foresight and visibility of collaboration between software practitioners involved in the project. During the pandemic, there is a need to promote sharing of responsibility based on feedbacks from end-users in ensuring transparency. Additionally, software managers are encouraged to incorporating better integration and collaboration in a remote environment between the development team members aimed at improving communication, team productivity and delivering of business value (Blueoptima, 2020b).

Furthermore, security is importance when working remotely to reduce infrastructure vulnerabilities (Bokolo, 2020). Therefore, software managers should provide an allocation of equipment logs for software developers, disk encryption should be initiated and regular password changes should be practiced (Blueoptima, 2020b). Also, up-to-date documentation can help software organizations to maintain productivity and efficiency during remote agile software development (Blueoptima, 2020b). Besides, evolving areas for improvement observed during the COVID-19 pandemic should be documented, as this can help for post-COVID-19 software development policies to better improve the productivity of software project efficiency and flexibility.

4. Discussion and implications

4.1 Discussion

The agile software development domain, being globalized and lean in structures, has become less affected by the pandemic. Although 94% of companies from other sectors have reported seeing disruptions (Ivanov, 2020). As some enterprises have been closed to reduce infection leading to some companies and industries been involved in producing products that are required to support health care during the pandemic (Elavarasan and Pugazhendhi, 2020). Accordingly, due to COVID-19, software practitioners were asked to WFH. This study aims to investigate if software practitioners' productivity was affected when working from home (Bao *et al.*, 2020). Accordingly, a significant number of software organizations across the globe are challenged to use initiatives to maintain productivity while lessening the impact of COVID-19 on their clients, employees and organizational resources.

However, developing software products using agile software methodology during the current pandemic requires two enhancements to the traditional agile approach. The first requires changing software team members' mindset (Shaheen, 2020; Schrage, 2021). This is because in traditional software practitioner manly aim to achieve specific requirements, ensuring that the developed software is functional from a technical viewpoint (Nagar, 2020). Whereas during and after the pandemic, the goal for developing software products is now geared toward developing software that customers want and probably will use. This necessitates the requirement for developing useful and innovative software based on market or societal requirements (Shaheen, 2020). In relation to productivity, findings from a survey of software developers reveal that software firms in China lost over $8.5m worth of output during the peak of COVID-19 infection, affecting productivity (Blueoptima, 2020a). Furthermore, findings from the study revealed that although software practitioners have been working digitally for years, the COVID-19 crises has resulted in an impromptu home office, leading to lower productivity.

Additionally, another recent study surveyed 2,000 software practitioners in 53 countries to identified how current work situations are affecting their organization's productivity (Rawcliffe, 2020). Conversely, findings from the study by Sathe and Panse (2023) suggested that agile software development teams that adopts to the agile attitude are better at responding to public health crisis and quick to adjust to changes as teams. The authors argued that the current mindset of individuals can improve their productivity during public health crises such as the COVID-19 pandemic. Hence, software practitioners' adapting to an agile mindset is critical for agile software development teams throughout a crisis as a reaction to changes in the working as well as environmental conditions of the office space.

Besides, findings from Rawcliffe (2020) suggest that software practitioners' productivity and emotional well-being are being affected mostly for parents, women and individuals with disabilities. Similarly, Rawcliffe (2020) revealed that poor home office ergonomic, poor crises preparation and fear of the pandemic are affecting software practitioners' productivity. But conversely, findings from Borowski (2020a) suggested that 45% of software practitioners mentioned that they are were more productive while in quarantine, while another 31% stated that they are working in the same amount, and finally 24% maintained that they are less productive working from home. Additionally, Borowski (2020a) indicated that many software practitioners would prefer working virtually and would even consider a pay reduction rather than returning to a physical office. Thus, findings from Borowski (2020a) suggest that during the pandemic, productivity has likely increased; however, it is unclear if this can be sustained in the long term if software practitioners continue working from home after post-COVID-19.

4.2 Practical/social implications

Findings from this research provide implications for software organizations to help software managers set expectations and prepare for agile software development in post-COVID-19 to prepare for what is to come. The findings can be used as an important part of software organization's playbook toward being operational during and after the current pandemic. This study provides practical implications to software organizations working remotely now and, in the future, to improve software practitioners' productivity. Moreover, this study advocates for software organizations to focus on improving the ergonomics of their employees' home workspaces not just within the pandemic but for potential future scenarios.

Findings from this study suggest that working from home improves flexibility for software practitioners toward productivity. Thus, this study suggests that software organizations should encourage a working from home policy for software projects based on the characteristics of the projects, e.g. project size, programming languages, time to delivery, etc. For instance, medium or large sized projects should allocate communication cost of working remotely by providing the relevant infrastructure required to facilitate project team communication (Bao *et al.*, 2020).

4.3 Theoretical implications

Theoretically, this study opens a new research area in agile software development and software engineering in crisis or emergency, grounded on secondary data from the literature. Although prior studies explored distributed teams and remote work, it is needed to explore the impact of crisis or emergency on software practitioners' productivity during crises such as the COVID-19 pandemic. More research is needed to understand how the crises impacts agile software development. Theoretically, this research has significant implications for software managers of agile software development projects. First, findings from this study identified factors (*postponed global hardware supplies, postponed software consultations, increase in unemployment, affect to health and wellness and increased usage of virtual collaborative platforms*) that emerged based on the COVID-19 pandemic that has resulted to changes in software organizations.

This study adds to the body of knowledge, as it identifies factors and offers new research areas that can be investigated either individually or collected to improve agile software development. Second, this research discusses issues faced by software practitioners that software managers could employ to effectively improve productivity in agile software development projects. Third, this research informs software managers on how they could do better in terms of improving productivity during the pandemic. Finally, during this pandemic, software managers might enable online reviews and encourage end-users to provide feedback to help improve productivity of software development (Kim, 2020).

5. Threats to validity

Threats in review studies are mostly assessed based on internal and external validity. Internal validity refers to the potential issues that impact the conclusion derived from secondary sources due to improper treatment of the area being explored. One possible threat to the internal validity relates to the bias in the selection of appropriate sources. In this current study, to address internal validity, a defined protocol with a rapid review search strategy was used to establish the review on COVID-19 pandemic and agile software development domain to provide implications for researchers, software practitioners and software managers. Besides, a rigorous research search strategy was used to reduce the internal threat to completeness of retrieval and to include all the sources relevant to

COVID-19 pandemic and agile software development. Thus, 60 sources were finally used to address the stated research questions in this study. The sources were published from 2019 to June 2022.

Notwithstanding, there is no guarantee that all appropriate sources are captured in this study, in view of topical discussion on COVID-19 pandemic and agile software development during 2020 till date (2022) are still emerging. Furthermore, relevant sources written in English languages were only included, which leads to the likelihood of omitting other relevant studies. Furthermore, threats to external validity relates to the issues that are related to the relationship of the issues being examined. Moreover, to mitigate external validity, this study considered multiple sources as seen in Figure 3. Respectively, considering external validity, the inclusion and exclusion criteria as well as QAC were specified (as seen in subsections 2.3.1–2.3.2) to carry out data synthesis for the study. The QAC check was used to identify credible studies that can provide sufficient evidence to the research question being explored. However, the QAC checklist was not used as the explored phenomenon in this study is constantly changing in research and practice.

6. Conclusion, limitations and future directions

Agile methods involve end-users and software practitioners' involvement in identifying and prioritizing requirements, providing feedback and guiding change through the course of the software development. Evidently, the COVID-19 pandemic has created a unique condition for software practitioners to explore research on how agile software development is impacted by adverse public health crises such as the pandemic. Accordingly, due to the COVID-19 pandemic, companies have transited to virtual workspace and software organizations have made a similar transition. However, research that explores the impact of the pandemic on agile software development and/or software organizational domain has received relatively limited attention. Accordingly, the main objective of this study is to explore agile software development toward the productivity of software practitioners amidst the pandemic.

Overall, this study presents an early assessment of the impacts of COVID-19 on software development productivity by examining the effect of social distancing and remote software development during COVID-19 pandemic and exploring the impact of software practitioners' productivity amidst the COVID-19 pandemic. The study further presents existing virtual collaborative platforms that are being adopted during WFH amidst the COVID-19 pandemic, and finally discuss issues and recommendations for improving the productivity of software practitioners during the COVID-19 pandemic and beyond in software organizations. The findings provide preliminary evidence from the literature regarding a phenomenological description of what is going on in agile software development rather than what must be done, particularly in terms of software development tools and methods.

Secondary data was collected from peer-reviewed journal articles, conference proceeding papers, preprint research papers, document reports and online sources. Findings from this study provide implications for software organizations on how to improve productivity during agile approaches used in developing innovative software. Future direction will involve investigating the identified factors (see subsection 3.3.2) in this study, as well as other organizational, technological and social factors that impact expanding agile approaches during post-COVID-19. Besides, in the future, survey questionnaires will be used to collect primary data from software practitioners to further investigate the impact of the COVID-19 pandemic on agile software development and software practitioners' productivity

during and after the COVID-19 pandemic. Statistical tools such as Statistical Package for Social Science and structural equation modeling will be used to analyze the survey data.

References

Adams, J.G. and Walls, R.M. (2020), "Supporting the health care workforce during the COVID-19 global epidemic", *Jama*, Vol. 323 No. 15, pp. 1439-1440.

Ågren, P., Knoph, E. and Berntsson Svensson, R. (2022), "Agile software development one year into the COVID-19 pandemic", *Empirical Software Engineering*, Vol. 27 No. 6, pp. 1-50.

Aldave, A., Vara, J.M., Granada, D. and Marcos, E. (2019), "Leveraging creativity in requirements elicitation within agile software development: a systematic literature review", *Journal of Systems and Software*, Vol. 157, p. 110396.

Anthony Jnr, B. (2021a), "Implications of telehealth and digital care solutions during COVID-19 pandemic: a qualitative literature review", *Informatics for Health and Social Care*, Vol. 46 No. 1, pp. 68-83.

Anthony Jnr, B. (2021b), "Integrating telemedicine to support digital health care for the management of COVID-19 pandemic", *International Journal of Healthcare Management*, Vol. 14 No. 1, pp. 280-289.

Anthony Jnr, B. and Abbas Petersen, S. (2021), "Examining the digitalisation of virtual enterprises amidst the COVID-19 pandemic: a systematic and meta-analysis", *Enterprise Information Systems*, Vol. 15 No. 5, pp. 617-650.

Bao, L., Li, T., Xia, X., Zhu, K., Li, H. and Yang, X. (2020), "How does working from home affect developer productivity? – A case study of Baidu During COVID-19 pandemic", *arXiv preprint arXiv:2005.13167*.

Batra, D. (2020), "Job-Work fit as a determinant of the acceptance of large-scale agile methodology", *Journal of Systems and Software*, Vol. 168, p. 110577.

Blueoptima (2020a), "Quantifying the impact of covid-19 on software developer productivity", available at: www.blueoptima.com/resource/report-quantifying-the-impact-of-covid-19-on-software-developer-productivity/ (accessed 31 March 2023).

Blueoptima (2020b), "Agile processes are key to efficient software development: effectively navigate your developer teams amidst COVID-19", available at: www.blueoptima.com/blog/agile-processes-are-key-to-efficient-software-development (accessed 22 June 2020).

Bokolo, A.J. (2020), "Exploring the adoption of telemedicine and virtual software for care of outpatients during and after COVID-19 pandemic", *Irish Journal of Medical Science (1971)*, Vol. 190 No. 1, pp. 1-10, doi: 10.1007/s11845-020-02299-z.

Bokolo, A.J. (2021), "Application of telemedicine and eHealth technology for clinical services in response to COVID-19 pandemic", *Health and Technology*, Vol. 11 No. 2, pp. 359-366.

Borowski, D. (2020a), "How the COVID-19 pandemic is impacting software development hiring", available at: https://medium.com/coderbyte/how-the-covid-19-pandemic-is-impacting-software-development-hiring-72243f41ac9e (accessed 22 June 2020).

Borowski, D. (2020b), "5 Tips from software developers for companies transitioning to remote product development", available at: https://blog.namely.com/transition-to-remote-product-development (accessed 22 June 2020).

Brown, E., Gray, R., Monaco, S.L., O'Donoghue, B., Nelson, B., Thompson, A., Francey, S. and McGorry, P. (2020), "The potential impact of COVID-19 on psychosis: a rapid review of contemporary epidemic and pandemic research", *Schizophrenia Research*, Vol. 222, pp. 79-87.

Butt, S.A., Misra, S., Anjum, M.W. and Hassan, S.A. (2021), "Agile project development issues during COVID-19", *International Conference on Lean and Agile Software Development*, Springer, *Cham*, pp. 59-70.

Da Camara, R., Marinho, M., Sampaio, S. and Cadete, S. (2020), "How do agile software startups deal with uncertainties by covid-19 pandemic?", *arXiv preprint arXiv:2006.13715*.

Elavarasan, R.M. and Pugazhendhi, R. (2020), "Restructured society and environment: a review on potential technological strategies to control the COVID-19 pandemic", *Science of The Total Environment*, Vol. 725, p. 138858.

Fernandes, N. (2020), "Economic effects of coronavirus outbreak (COVID-19) on the world economy", *Available at SSRN 3557504*.

Ganji, K. and Parimi, S. (2021), "ANN model for users' perception on IOT based smart healthcare monitoring devices and its impact with the effect of COVID-19", *Journal of Science and Technology Policy Management*, Vol. 13 No. 1, pp. 6-21.

Griffin, L. (2021), "Implementing lean principles in scrum to adapt to remote work in a covid-19 impacted software team", *International Conference on Lean and Agile Software Development*, Springer, *Cham*, pp. 177-184.

Ivanov, D. (2020), "Predicting the impacts of epidemic outbreaks on global supply chains: a simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case", *Transportation Research. Part E, Logistics and Transportation Review*, Vol. 136, p. 101922.

JHU (2020), "COVID-19 dashboard by the center for systems science and engineering (CSSE) at Johns Hopkins University (JHU)", available at: https://coronavirus.jhu.edu/map.html (accessed 23 June 2020).

Jnr, B.A. (2019), "Validating the usability attributes of AHP-software risk prioritization model using partial least square-structural equation modeling", *Journal of Science and Technology Policy Management*, Vol. 10 No. 2, pp. 404-430.

Jnr, B.A. (2020), "Use of telemedicine and virtual care for remote treatment in response to COVID-19 pandemic", *Journal of Medical Systems*, Vol. 44 No. 7, pp. 1-9.

Jnr, B.A., Nweke, L.O. and Al-Sharafi, M.A. (2020), "Applying software-defined networking to support telemedicine health consultation during and post covid-19 era", *Health and Technology*, Vol. 11 No. 2, pp. 395-403.

Kettunen, P., Gustavsson, T., Laanti, M., Tjernsten, A., Mikkonen, T. and Männistö, T. (2021), "Impacts of COVID-19 pandemic for software development in nordic companies–agility helps to respond", *International Conference on Agile Software Development*, Springer, *Cham*, pp. 33-41.

Kim, R.Y. (2020), "The impact of COVID-19 on consumers: preparing for digital sales", *IEEE Engineering Management Review*, Vol. 48 No. 3, pp. 212-218.

Kobielus, J. (2020), "Coding together apart: software development after COVID-19", available at: www.infoworld.com/article/3537168/coding-together-apart-software-development-after-covid-19.html (accessed 22 June 2020).

Kramer, A. and Kramer, K.Z. (2020), "The potential impact of the covid-19 pandemic on occupational status, work from home, and occupational mobility", *Journal of Vocational Behavior*, Vol. 119, p. 103442.

Kropp, M., Meier, A., Anslow, C. and Biddle, R. (2020), "Satisfaction and its correlates in agile software development", *Journal of Systems and Software*, Vol. 164, p. 110544.

Kude, T. (2020), "Agile software development teams During and After COVID-19", available at: http://knowledge.essec.edu/en/innovation/agile-software-development-during-after-COVID19.html (accessed 22 June 2020).

Lakshmi Priyadarsini, S. and Suresh, M. (2020), "Factors influencing the epidemiological characteristics of pandemic COVID-19: a TISM approach", *International Journal of Healthcare Management*, Vol. 13 No. 2, pp. 89-98.

Lindsjørn, Y., Almås, S. and Stray, V. (2021), "Exploring motivation and teamwork in a large software engineering capstone course during the coronavirus pandemic", *arXiv preprint arXiv:2103.08020*.

Malgonde, O. and Chari, K. (2019), "An ensemble-based model for predicting agile software development effort", *Empirical Software Engineering*, Vol. 24 No. 2, pp. 1017-1055.

Mancl, D. and Fraser, S.D. (2020), "COVID-19's influence on the future of agile", *International Conference on Agile Software Development*, Springer, *Cham*, pp. 309-316.

Marek, K., Wińska, E. and Dąbrowski, W. (2021), "The state of agile software development teams during the covid-19 pandemic", *International Conference on Lean and Agile Software Development*, Springer, *Cham*, pp. 24-39.

Marinho, M., Amorim, L., Camara, R., Oliveira, B.R., Sobral, M. and Sampaio, S. (2021), "Happier and further by going together: the importance of software team behaviour during the COVID-19 pandemic", *Technology in Society*, Vol. 67, p. 101799.

Nagar, T. (2020), "How will the coronavirus impact the software industry?", available at: https://customerthink.com/how-will-the-coronavirus-impact-the-software-industry/ (accessed 22 June 2020).

Nazir, S., Price, B., Surendra, N.C. and Kopp, K. (2022), "Adapting agile development practices for hyper-agile environments: lessons learned from a COVID-19 emergency response research project", *Information Technology and Management*, Vol. 23 No. 3, pp. 193-211.

Neumann, M. and Bogdanov, Y. (2022), "The impact of covid 19 on agile software development: a systematic literature review", *Proceedings of the 55th HI International Conference on System Sciences*, pp. 7350-7359.

Neumann, M., Bogdanov, Y. and Sager, S. (2022), "The covid 19 pandemic and its effects on agile software development", *2022 The 5th International Conference on Software Engineering and Information Management (ICSIM)*, pp. 51-60.

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M. and Agha, R. (2020), "The socio-economic implications of the coronavirus pandemic (COVID-19): a review", *International Journal of Surgery*, Vol. 78, pp. 185-193.

Ope Olabiwonnu, F., Haakon Bakken, T. and Anthony Jnr, B. (2022), "The role of hydropower in renewable energy sector toward co2 emission reduction during the COVID-19 pandemic", *International Journal of Green Energy*, Vol. 19 No. 1, pp. 52-61.

Pinkus, C. (2020), "Software development during a pandemic COVID-19, software developers and becoming All-Remote (part 1)", available at: https://jaxenter.com/covid-19-remote-170121.html (accessed 22 June 2020).

Ralph, P., Baltes, S., Adisaputri, G., Torkar, R., Kovalenko, V., Kalinowski, M., Novielli, N., Yoo, S., Devroey, X., Tan, X. and Zhou, M. (2020), "Pandemic programming: how COVID-19 affects software developers and how their organizations can help", *Empirical Software Engineering*, Vol. 25, pp. 4927-4961.

Rawcliffe, R. (2020), "Pandemic programming: international study reveals impacts of COVID-19 on software practitioners", available at: www.dal.ca/news/2020/05/07/pandemic-programming–international-study-reveals-impacts-of-cov.html (accessed 22 June 2020).

Russo, D., Hanel, P.H., Altnickel, S. and Van Berkel, N. (2021), "The daily life of software engineers during the covid-19 pandemic", *2021 IEEE/ACM 43rd International Conference on Software Engineering: Software Engineering in Practice (ICSE-SEIP)*, pp. 364-373.

Sathe, C.A. and Panse, C. (2023), "Analyzing the impact of agile mindset adoption on software development teams productivity during COVID-19", *Journal of Advances in Management Research*, Vol. 20 No. 1, pp. 96-115.

Schmidt, P. and Gutfreund, K. (2022), "Agile software development during the COVID-19 pandemic: a technology company survey", *HICSS*, pp. 1-10.

Schrage, Z. (2021), "How can software development teams be controlled during the COVID-19 pandemic", *Digital Responses to Covid-19*, Springer, Cham, pp. 87-103.

Shaheen, A. (2020), "Software engineering takes on new meaning in the COVID-19 pandemic", available at: https://digitally.cognizant.com/software-engineering-takes-on-new-meaning-in-the-covid-19-pandemic-codex5676/ (accessed 22 June 2020).

Skelton, S.K. (2020), "Coronavirus: how app developers large and small are working to help fight covid-19", available at: www.computerweekly.com/feature/Coronavirus-how-app-developers-large-and-small-are-working-to-help-fight-Covid-19 (accessed 22 June 2020).

Slabe-Erker, R. and Primc, K. (2021), "ICT-enabled organisational flexibility to support sustainable growth in Europe amidst a pandemic", *Journal of Science and Technology Policy Management*.

Spurk, D. and Straub, C. (2020), "Flexible employment relationships and careers in times of the COVID-19 pandemic", *Journal of Vocational Behavior*, Vol. 119, p. 103435.

Topp, J., Hille, J.H., Neumann, M. and Mötefindt, D. (2022), "How a 4-Day work week and remote work affect agile software development teams", *International Conference on Lean and Agile Software Development*, *Springer*, *Cham*, pp. 61-77.

Williams, C.C. and Kayaoglu, A. (2020), "COVID-19 and undeclared work: impacts and policy responses in Europe", *The Service Industries Journal*, Vol. 40 Nos 13/14, pp. 914-931.

Xaverius, F. (2020), "Manage software development project using virtual teams during COVID-19", *Available at SSRN 3591096*.

Further reading

Blueoptima (2020c), "How engineering leaders can support remote working teams during coronavirus pandemic", available at: www.blueoptima.com/blog/coronavirus-impact-on-software-development-how-engineering-leaders-can-support-remote-working-teams (accessed 22 June 2020).

Moore, J.H., Barnett, I., Boland, M.R., Chen, Y., Demiris, G., Gonzalez-Hernandez, G., Herman, D.S., Himes, B.E., Hubbard, R.A., Kim, D. and Morris, J.S. (2020), "Ideas for how informaticians can get involved with COVID-19 research", *BioData Mining*, Vol. 13 No. 3, pp. 1-16.

About the author

Bokolo Anthony Jnr is currently a Senior Researcher at the Department of Applied Data Science, Institute for Energy Technology (IFE), Halden, Norway. He is also an Associate Professor at the Department of Computer Science and Communication, Østfold University College, Norway. Previously he was a Post-Doctoral Fellow at the Department of Computer Science, Norwegian University of Science and Technology (NTNU), Trondheim, Norway. He currently works on research and development in Digital Systems, Smart Cities, Data Ecosystems, Energy Informatics and Sustainability. His e-mail address is anthony.bokolo@ife.no. Bokolo Anthony Jnr can be contacted at: bkanjr@gmail.com