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Examining the Digitalization of Virtual Enterprises Amidst the COVID-19 Pandemic: A Systematic and Meta-Analysis

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Abstract

Enterprises are surviving in a digital transitioning society, where the creation of strategic alliances is one important result of this constant change during the coronavirus 2019 (COVID-19) pandemic. A medium of conducting business where organizations can share their main capabilities in order to strive in a pandemic is the creation of Virtual Enterprises (VE). But despite increasing research interest in VE, there is still lacunae in understanding the conceptualization of digitalization of VE operations during crises. Therefore, this provides a review of extant literature and meta-analysis of 55 VE research articles to present the theoretical underpinning concept of VE digitalization.

Keywords: Enterprise systems; Enterprise digitalization; Virtual enterprises; Enterprise factors; Enterprise life cycle; COVID-19 pandemic.

1. Introduction

The current pandemic has disrupted enterprise productivity forcing changes to enterprise operations (Nagar, 2020). Thus, enterprises which comprises of organizations created for business ventures (Castro et al., 2012; Jnr et al., 2017), are facing an increasingly changing business environment due to the coronavirus 2019 (COVID-19) pandemic. Accordingly, organizations are collaborating with other organizations who have complementary capabilities operated as a node in the network referred to as a Virtual Enterprise (VE) (Camarinha-Matos et al., 2000; Petersen et al., 2001; Kim et al., 2006). What generally involves the collaborative partnership between organizations in value chains, has in recent times become an important practice for firm's survival during this crisis (Breu et al., 2001). A VE is a temporary corporation that combines member organizations' core capabilities to exploit fast changing economic opportunities (Chen et al., 2011). VE overcomes geographical constraints by allowing businesses to collaborate and address their inadequacies through exchange of skills and services (Sadigh et al., 2017). VEs offer new prospects to businesses operating with an increasing number of stakeholders (partners, consumers, merchants, and others) in a global corporate environment (Esposito and Evangelista, 2014).

VE is an interoperable network of pre-existing organizations with a mutual goal, where the organizations can function together as a single enterprise (Grecu and Ghita, 2015). VE is enhanced by the existing economic and market conditions facilitated by recent developments and innovations in Information and Communication Technology (ICT) termed as digitalization or digital transformation (Chen et al., 2011; Sadigh et al., 2017). Accordingly, digitalization is the conversion of analog information into a digital format, for instance "into zeros and ones" such that computers can process, transmit, and store such information (Berman, 2012). Researchers such as Verhoef et al. (2019) refers to digitalization as a change of analog tasks to

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digital or conceptualized it as the incorporation of Information Technology (IT) within existing operations. Digitalization defines how digital technologies or IT can be utilized to change current business processes. In digitalization, IT serves as a crucial enabler to seize new business possibilities by changing current business activities, such as business relationship management, communication, or distribution. VEs use digital technologies to enhance or transit from sales of physical products by offering innovative services (Vail, 2019).

In this regard, digitalization in a VE is much more than a simple process redesign. It involves structuring business operations to completely leverage companies' core competence through digital technology to achieve competitive advantage (Liu et al., 2011). Through digitalization, VEs apply digital technologies to improve existing business operations by allowing a more effective coordination between processes, and/or by creating additional value by enhancing end-user experiences (Berman, 2012). Hence, digitalization is an important phase that introduces new business models by implementing innovative business logic that creates and capture value (Verhoef et al., 2019). Presently, the economic competition among businesses has increased and successful VEs need to digitalize their services (Kempegowda and Chaczko, 2018; Vail, 2019; Verhoef et al., 2019). Therefore, in facing up to these changes, businesses are exploring new inter-firm organizational relationship models that better fit the new environment for achieving a competitive advantage (Kim et al., 2006; Sari et al., 2007; Javed and Yasir, 2019). Hence, there is a need for approaches that offer more flexible organizational structures allowing swift adaptation to change and intensive deployment of ICT in order to exploit innovation and collaborative relationships in a more effective and efficient way (Esposito and Evangelista, 2014; Zangiacomi et al., 2020).

Besides, according to Sari et al. (2007) there is lack of a comprehensive approach for VEs that outlines and structures the lifecycle and associated activities that are needed to facilitate the management of VEs during global crises. Thus, there is a need for an approach to provide guidelines on the comprehensive life cycle process to be adopted to digitalize VE (Sari et al., 2007). Besides, notwithstanding increasing research in the VE domain, there is little research investigated towards the digitalization of VEs. Although, prior studies (Chen et al., 2011; Esposito and Evangelista, 2014; Sadigh et al., 2017; Vail, 2019) have contributed to the development of approaches to improve VE operations, there is still a need to investigate the factors for improving digitalization of a VE's life cycle operations during the COVID-19 pandemic. Therefore, this study aims to systematically reviews and synthesizes prior studies that explored the overview, factors, and lifecycle of VE digitalization in order to achieve meta-analysis of the collected studies in investigating the following six research questions:

RQ1: What are the research methods, countries, contexts, and publication year of selected VE digitalization studies?

RQ2. What are the types of enterprise networks, overview and characteristics of VE?

RQ3. What are the current digital innovations employed in VE to improve business operations during the COVID-19 pandemic?

RQ4. What are the factors that inhibits digitalization of VEs during the COVID-19 pandemic?

RQ5. Which prior studies proposed approaches related to digitalization of VE operations?

RQ6. What are the general functional requirements for the phases of VE's life cycle?

Accordingly, to address the research questions, this study reviews and reports on the theoretical and practical underpinnings of the concept of VE digitalization. The remainder of the article is organized as follows. Section 2 is the literature review. Section 3 is the research methodology and section 4 describes the findings and discussion. Section 5 is the implications and conclusion.

2. Literature Review

The concept of VE is mostly technology driven and is based on the use of information systems. Research on VE have appeared since 1990s, but the term "virtual enterprise" was first coined in the late 1980s with reference to virtual (invisible) links among businesses supported by ICT. Ever since, several studies have been published towards improving VE operations, but only a few studies have conducted review on VE. Among these studies Seyedghorban et al. (2020) explored supply chain digitalization in enterprise based on past, present and future. The researchers provided a clear discussion on supply chain digitalization by examining what constitutes the fundamental structure of digitalization, topics that have been explored, focus areas, and classification of supply chain digitalization. Another study by Javed and Yasir (2019) presented a review on virtual social enterprise by modelling the sustainability of digital enterprise. The study explored evolving area of social entrepreneurship that deploys ICT-based systems and networking with global partners as a VE network to create economic and social values across borders.

A recent study by Verhoef et al. (2019) provided a research agenda on digital transformation grounded on a multidisciplinary approach. The study mentioned that digital transformation comprises of three phases (digitization, digitalization, and digital transformation), and specified growth strategies for how enterprises can digitalize their capabilities and assets for successful digital transformation. Vial (2019) conducted a review to understanding digital transformation in enterprise. The author suggested a framework to support digital transformation as a process where digitalization creates disruptions causing strategic responses from enterprises that seek to change their value creation operations while managing organizational barriers and structural changes that affect the negative and positive outcomes of this process. Jr et al. (2017) carried out a study to structurally review and analyze Green IT system practice for sustainable enterprise operations. Their research focused to support virtual enterprises reduce the amount of energy utilized, minimize high cost incurred in business process to achieve sustainability.

Gölzer and Fritzsche (2017) conducted a review on data-oriented operations management for digital transformation in industrial domains. The authors identified the different areas of action for operations logistics related to data processing by exploring the impact of big data on industrial processes. Their review focused on changes in data management resulting from digitalization in the industrial sector. Another systematic review of sustainable implementation and adoption of green practice in enterprises was documented

by Jnr et al. (2017). The authors attempted to provide a clear understanding of how practitioners and decision makers can employ sustainable practices in enterprise operations. In addition, the authors in Esposito and Evangelista (2014) presented a review study with specific focus on VE models. Findings from the review presented six topics in VE research to be considered as basics for the theoretical concept of VE and five areas which can be classified as a VE framework.

Based on the literature, the reviewed studies investigated VE in the context of sustainability (Jnr et al., 2017; Jr et al., 2017; Javed and Yasir, 2019), digitalization (Gölzer and Fritzsche, 2017; Vial, 2019; Verhoef et al., 2019; Seyedghorban et al., 2020), and conceptualization (Esposito and Evangelista, 2014) in improving competitiveness. However, only fewer studies explored the life cycle of a VE and factors that inhibits VE operations during crises such as in the COVID-19 pandemic. Hence, this study is motivated to carry out this systematic review to fill the gap in knowledge in this aspect by providing a review on general functional requirements for VE's life cycle and factors that inhibits digitalization of VEs during the COVID-19 pandemic.

3. Research Methodology

It is important to carry out a comprehensive literature review before starting any research investigation (Esposito and Evangelista, 2014). A Literature review helps to capture the information which supports concepts' developments, help to find research limitations that exists and discloses areas where previous studies have not explored (Jr et al. 2017). Likewise, a systematic literature review (SLR) is a review that is based on unambiguous research questions, defines and explores relevant studies, and lastly assesses the quality of the studies based on specified criteria (Seyedghorban et al., 2020). Accordingly, this study followed the recommendation postulated by Jnr et al. (2017); Verhoef et al. (2019); Vial (2019) in reporting a systematic review. Therefore, the research design for this study comprises of five phases which includes the specification of inclusion and exclusion criteria, presentation of search strategies and data sources, quality assessment, data coding and analysis, and lastly the findings. The research design of this review study is shown in Figure 1.

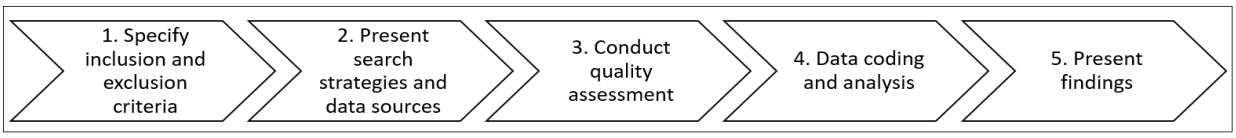

Figure 1 Research design

Figure 1 depicts the research design for this study, where each phase is discussed in the subsequent sub-sections.

3.1. Inclusion and Exclusion Criteria

The inclusion and exclusion criteria (Table 1) and quality assessment criteria are employed as the sampling/selection methods used to select the articles involved in this study. The inclusion and exclusion criteria are defined in Table 1. A study is included if it satisfies the criteria in the inclusion column and removed if it meets any of the exclusion criteria.

Table 1 Inclusion and exclusion criteria

Inclusion	Exclusion
• Should involve background of VE digitalization, factors or life cycle of VE.	• Studies that do not present background of VE digitalization, factors or life cycle of VE.
• Should employ a model, approach, framework or theory for investigating VE digitalization.	• Models, approach, frameworks or theories used in contexts other than VE digitalization.
• Should be written in English and published between 1999 to 2020.	• Studies that use languages other than English.
• VE studies that employed a technique such as agents, etc. for VE digitalization.	• VE studies that do not involve any technique.

3.2. Search Strategies and Data Sources

The articles utilized in this study were retrieved through an extensive search of prior studies through online databases which included Google Scholar, ScienceDirect, Emerald, IEEE, Sage, ACM, Taylor & Francis, Inderscience, IGI Global, Springer, and Wiley (Jr et al., 2017; Javed and Yasir, 2019). The search was undertaken in March 2020. The search terms comprise the keywords ((“virtual enterprise” OR “digital transformation of virtual enterprise” OR “digitalization of virtual enterprise” OR “virtual enterprise lifecycle”) AND (“technique” OR “implementation” OR “adoption” OR “approach” OR “model” OR “framework” OR “theory”)) AND (“factors” OR “variables”)). The mixture of the keywords is a crucial step in any systematic review as it defines articles that will be retrieved (Jnr et al., 2017). These keywords were selected to get the appropriate sources to provide empirical evidence regarding the research questions being explored in this study. Also, the selected keywords relate to the research questions to be investigated.

Figure 2 depicts the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart which was employed for searching and refining of the articles as previously utilized by Verhoef et al. (2019). The search output presented 309 articles using the above stated keywords. 10 articles were establish as duplicates, as such were removed. Therefore, resulted to 299 articles. The authors checked the articles against the inclusion and exclusion criteria and removed 197 papers since they were not related to VE digitalization or VE lifecycle or factors that inhibits VE resulting to 102 articles. The remaining 102 studies was checked if journal or conference proceedings were indexed in ISI Web of Science or Scopus database and another 47 studies were excluded resulting to 55 studies. Accordingly, 55 research articles meet the inclusion/quality assessment criteria and were included in the study to address the research questions.

3.3.Quality Assessment

One of the important criteria that is required to be checked along with the inclusion and exclusion criteria is the quality assessment. As recommended by Esposito and Evangelista (2014) a higher level of rigorousness of studies is employed to check quality of papers. To this end, a quality assessment checklist which checks if the selected papers were indexed in ISI Web of Science or Scopus database was employed as a means for evaluating the quality of the studies selected (n = 102) (see Figure 2). The checklist was adapted from recommendation from Esposito and Evangelista (2014); Verhoef et al. (2019). Respectively, only 55 selected

studies passed the quality assessment and are eligible to be utilized for further meta-analysis. 4 additional web sources on COVID-19 and enterprise are included (see reference section).

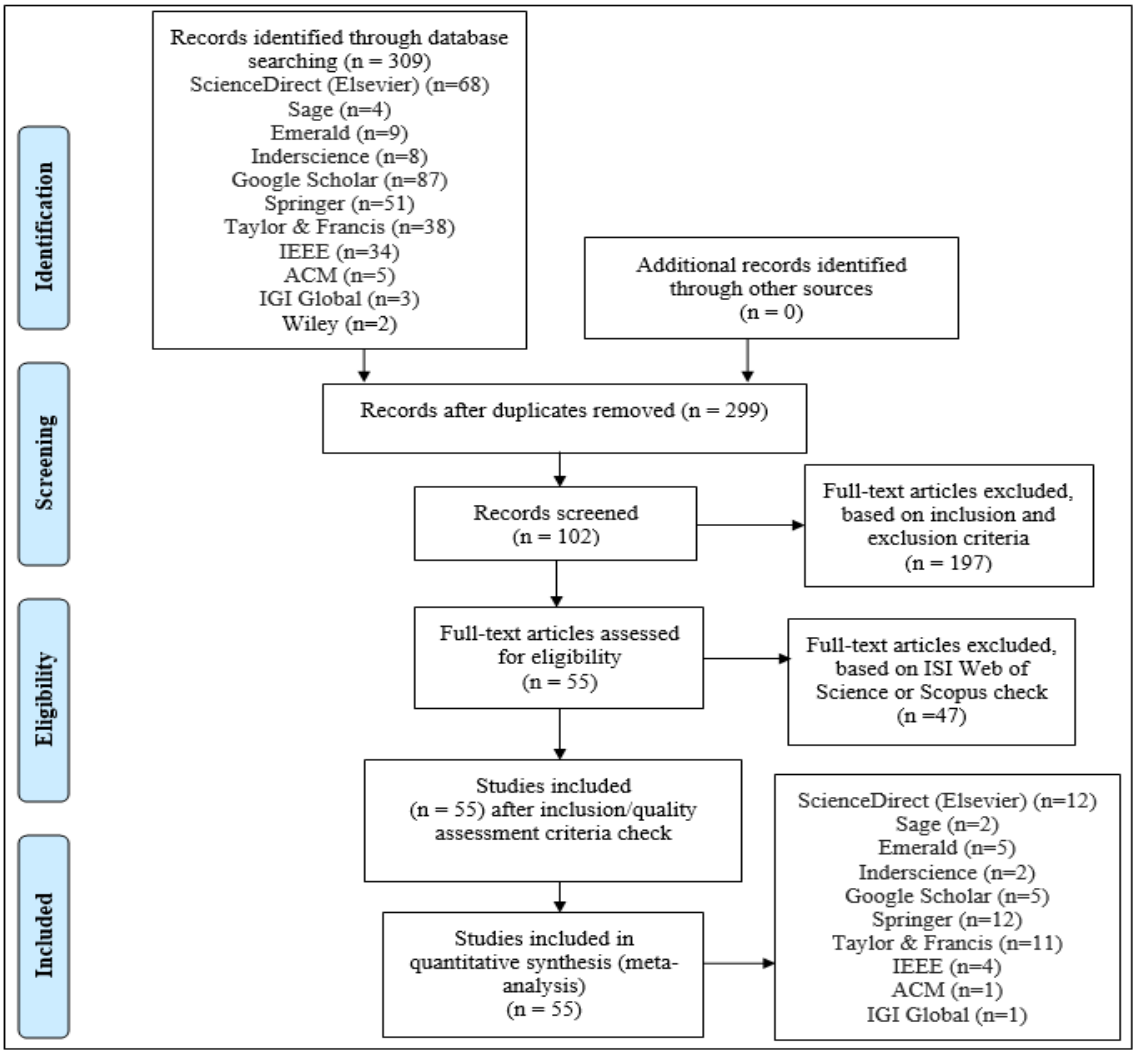

Figure 2 PRISMA flowchart for the selected articles

3.4.Data Coding and Analysis

The information of the journals and conference proceedings are shown in Figure 4 and the complete bibliographic information of the studies chosen for meta-analysis are presented in the reference section. The 55 selected studies were reviewed, and data related to the research questions were coded and examined in detail and the results of the meta-analysis are defined in the subsequent sections.

4. Findings and Discussion

Based on the selected 55 studies published in regard to theoretical underpinning concept of VE digitalization from 1999 to 2020, this study reports the findings of this systematic review in relation to the specified six research questions.

4.1.RQ1. Research Methods, Countries, Contexts, and Publication Year of Studies

With regard to the first research question, the findings for distribution of studies related to VE digitalization based on year of publication is presented in Figure 3. As shown, the studies are ranged from 1999 to 2020. Findings suggest that within 2004, 2008, and 2016 no studies related to the research question were included, hence these years were not included in Figure 3. Findings from Figure 3 indicate that there seems to be an increase in studies on VE over the last few years as seen from 1994 to 2020, with 2019 being the highest with publications on VE digitalization with 11 studies published. This finding is analogous with results from the literature (Barbosa et al., 2019; Vail, 2019). It is evident that the frequency of these publications in 2019 could be accredited to the fact that the intensity of digital innovation in 2019 increased across enterprise operations. With deployment of Internet of Things (IoT), machine learning, big data analytics, blockchain, cloud computing, etc. has improved mainly in developed and developing countries across the world (El Hilali and El Manouar, 2018a; Kempegowda and Chaczko, 2018).

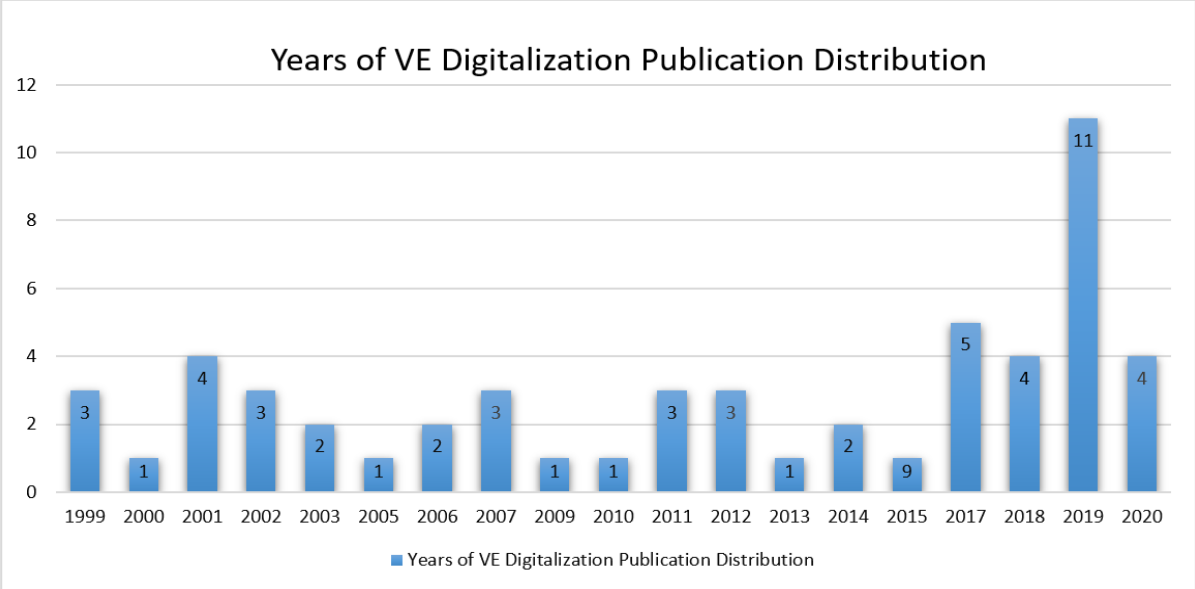

Figure 3 Distribution of selected VE digitalization studies in terms of years

Figure 4 depicts the selected studies journal and conference proceeding articles, where 36 papers are journal articles and 19 are conference proceeding articles. 5 articles were published in production planning & control, 3 articles were published in procedia computer science, 2 articles were published in enterprise information systems and international journal of computer integrated manufacturing each. The remaining were published in other 24 journals. Similarly, 6 articles were published in the working conference on virtual enterprises, 2 articles were published in the proceedings of the third international conference on smart city applications, and the remaining 11conference papers were published in other proceedings.

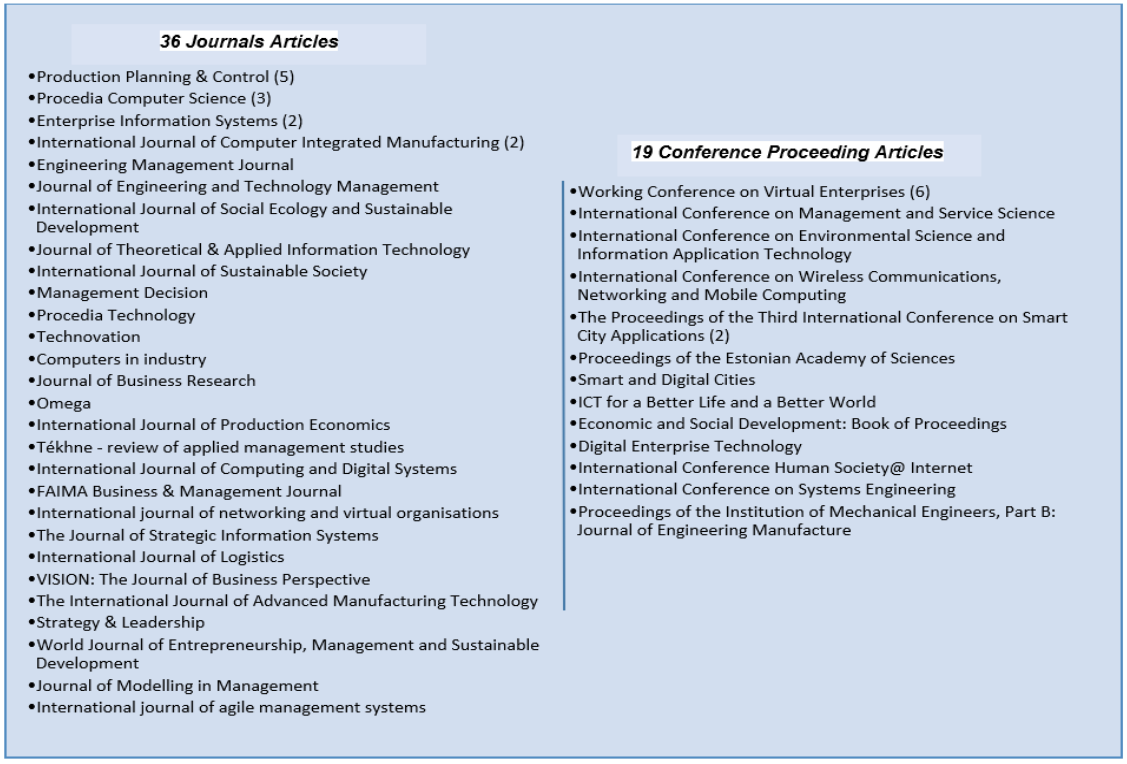

Figure 4 Selected studies journal and conference proceeding articles

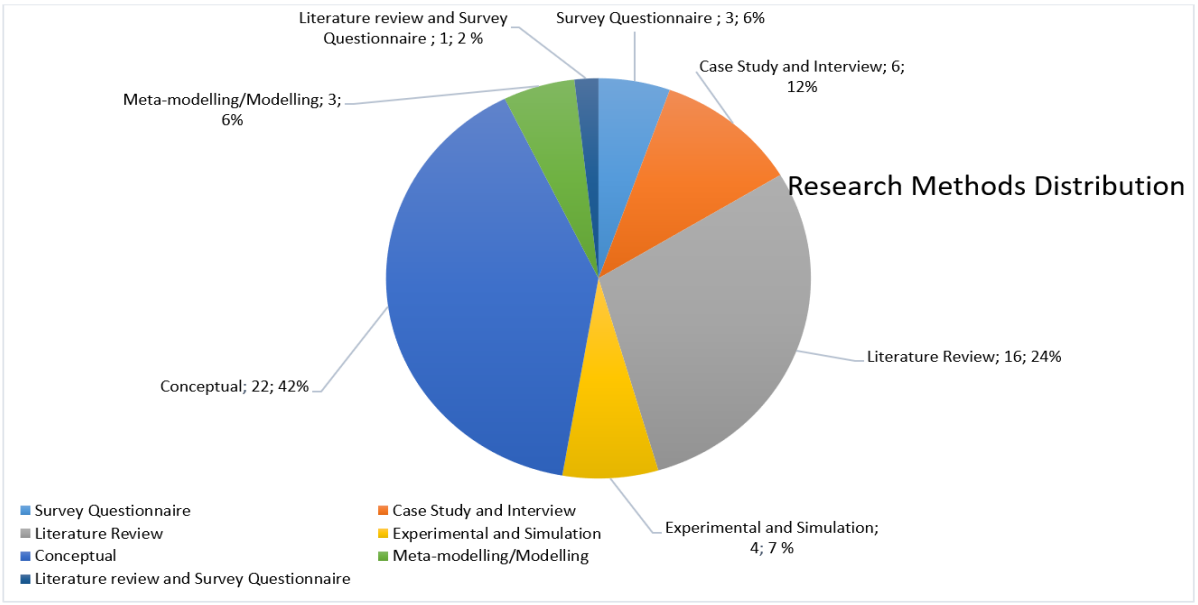

Figure 5 Distribution of selected VE digitalization studies in terms of research methods

Considering the research methodology applied in the 55 studies, findings from Figure 5 show that conceptual studies were the most employed method (N = 22, 42%), where no data collection was reported as the studies were mainly theoretical. This result is consistent with findings from recent study (Seyedghorban et al., 2020), which reveals that most of the studies published in supply chain digitalization were mostly conceptual. Next are studies that were grounded on literature reviews or secondary data with (N = 16, 24%). Following, are studies that adopted case study methodology and interviews with (N = 6, 12%), and studies that employed experimentation and simulation for validation (N = 4, 8%). For the remaining

studies, (N = 3, 6%) employed survey questionnaire, and meta-modelling/modelling with (N = 3, 6%) individually, and lastly only (N = 1, 2%) for study that employed mixed mode method comprising of a literature review and a survey questionnaire. These findings are analogous with prior review studies conducted by (Esposito and Evangelista, 2014; Jnr et al., 2017; Vail, 2019) who discussed that there is a need for quantitative studies that explored the digitalization of VE. Furthermore, this finding is consistent with the fact that literature review is considered the most suitable data collection method for collecting data in confirming theories related to digitalization of VE (Jr et al., 2017; Javed and Yasir, 2019; Verhoef et al., 2019).

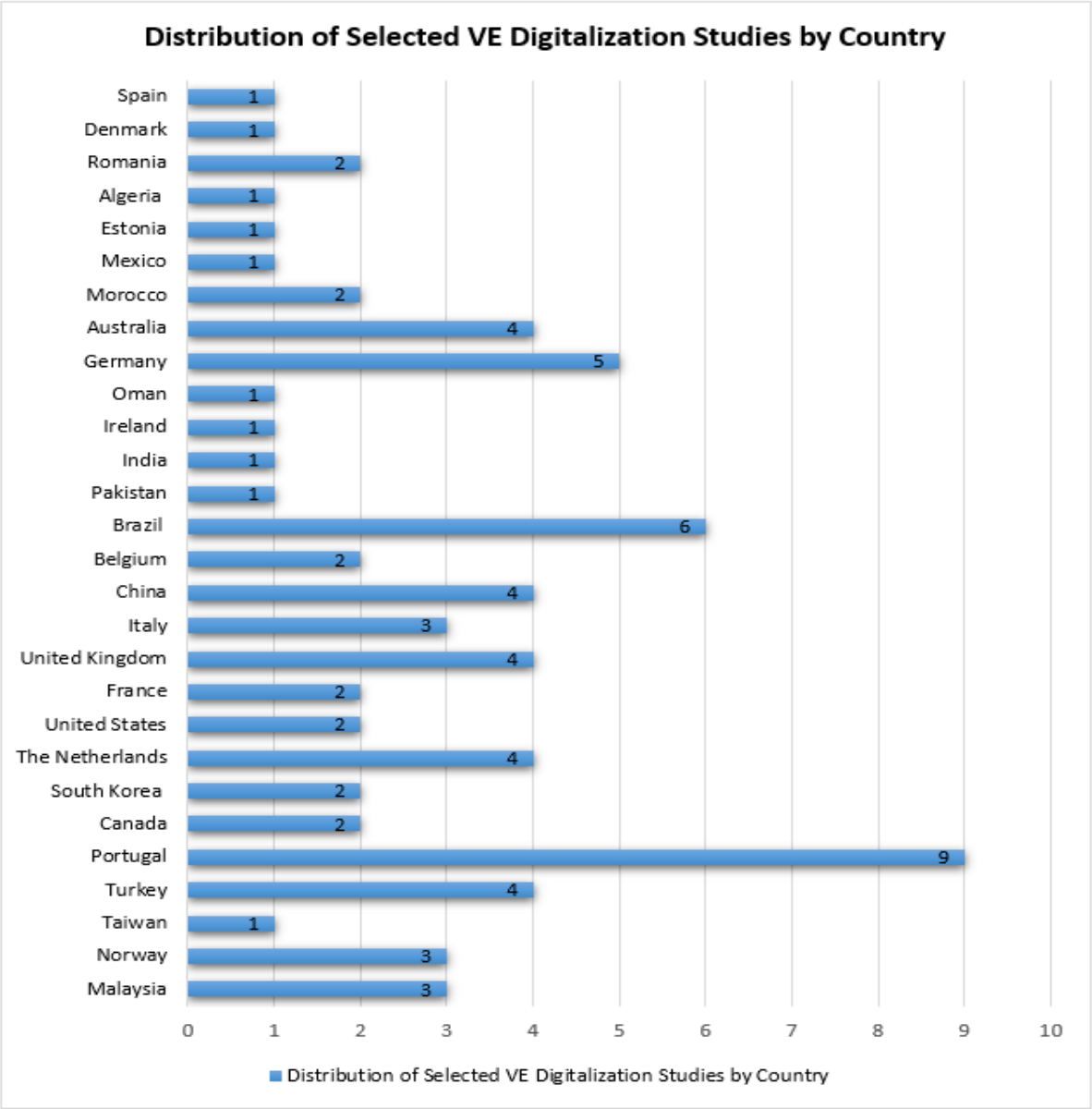

Figure 6 Distribution of selected VE digitalization studies in terms of country

With regard to the 55 studies country distribution, findings from Figure 6 shows research related to VE digitalization. Accordingly, most of the studies are conducted in Portugal (N = 9). Next, research articles related to VE digitalization was carried out in Brazil (N = 6) and Germany with (N = 5), and Australia, China, United Kingdom, The Netherlands

and Turkey with (N = 4) individually. This was followed by Italy, Norway, and Malaysia with (N =3). Then, Romania, Morocco, France, United States, Belgium, South Korea, and Canada, with (N =2) respectively. Lastly, (N = 1) study was each conducted in Denmark, Algeria, Estonia, Mexico, Oman, Ireland, India, Spain, Pakistan, India, and Taiwan. These findings also suggest that most of the leading researchers of VE digitalization such as Rocha and Oliveira (1999); Camarinha-Matos et al., (2000); Camarinha-Matos et al., (2003) are from Portugal and Brazil, who are some of the most cited researchers from "working conference on virtual enterprises – PRO-VE" in the VE domain.

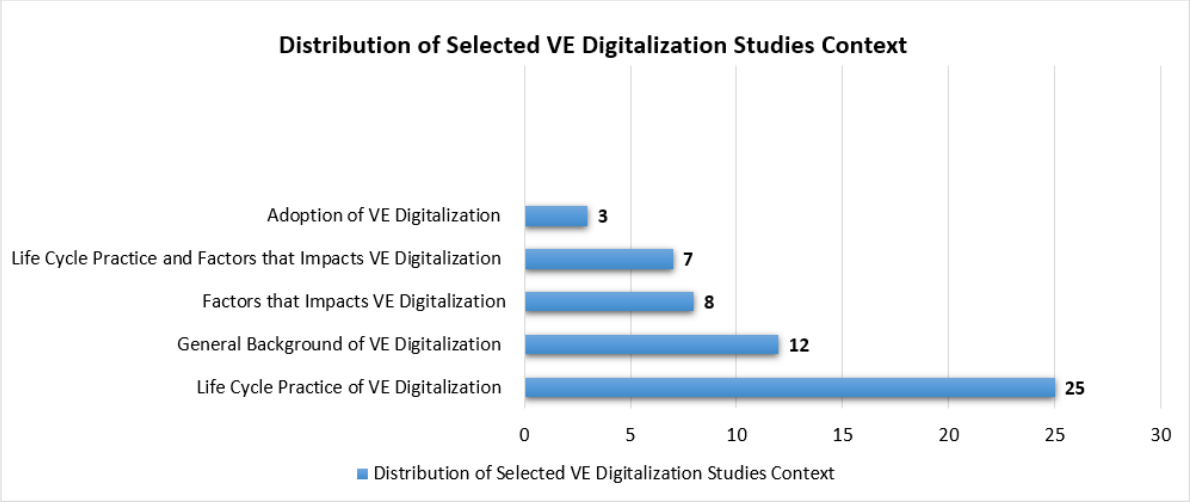

Figure 7 Distribution of selected VE digitalization studies context

Considering the selected studies' context distribution of VE digitalization findings from Figure 7 indicate that (N = 25) studies mainly explored the life cycle practice employed for VE digitalization. This finding is consistent with results from prior studies (Petersen et al., 2001; Sari et al., 2007; Cong et al., 2010) which encouraged the need for studies that improve the life cycle process of VE operations (Tølle et al., 2002; Romero and Molina, 2011). In addition, findings from Figure 7 reveal that (N = 12) studies mainly investigated the general background of VE digitalization by considering the theoretical perspective. This finding is very consistent with results from the literature (Camarinha-Matos and Afsarmanesh, 1999; Al Hadidi and Baghdadi, 2019), where the authors mentioned the need for studies that explore the theoretical underpinning of VE operations.

Furthermore, the findings suggest that (N = 8) studies mainly examined factors that influence VE digitalization. Similarly, this finding is analogous with results from studies conducted by prior researchers (Grecu and Ghita, 2015; Agrawal et al., 2019) which revealed that there are limited studies that explored drivers related VE operations. Additionally, findings from Figure 7 show that (N = 7) studies that concurrently examined lifecycles and factors that impacts VE digitalization, this aligns with findings presented by Sadigh et al. (2017); Verhoef et al. (2019). Where the authors called for theoretical and empirical research to improve VE practice. Lastly, (N = 3) study investigated the adoption of VE. This finding suggests that there are limited studies that examine how to improve adoption of VE as mentioned by Esposito and Evangelista (2014). Accordingly, this review presents the life cycle for VE digitalization and factors that influence VE digitalization.

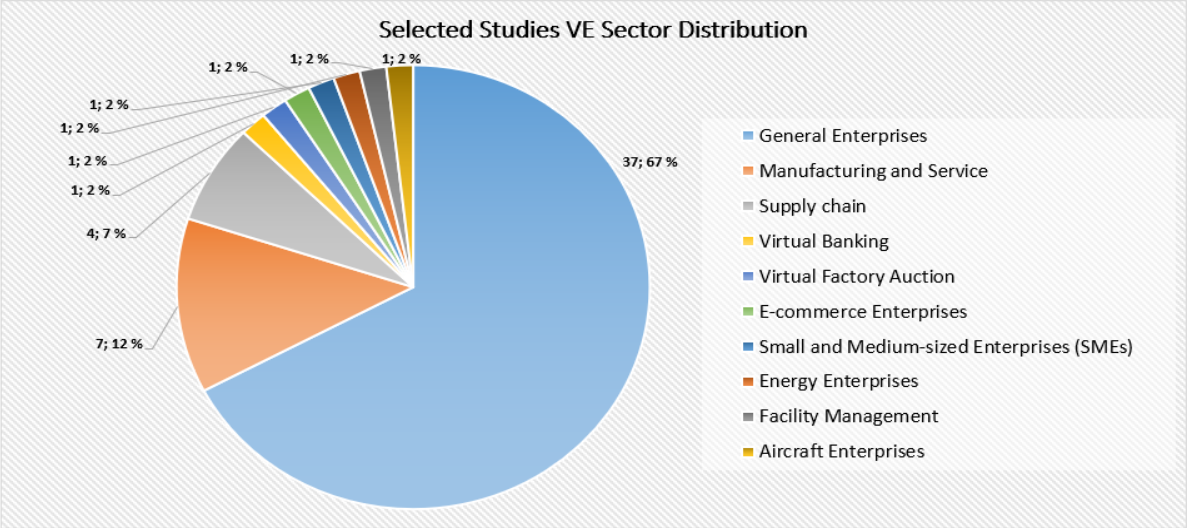

Figure 8 Distribution of selected VE sector context

Figure 8 illustrates the sectors of the selected studies, where the results indicates that most of the studies (N = 37, 67%) are based on general enterprises (comprises of several enterprises). This result is in line with findings from Sadigh et al. (2017) where the researchers found out that most VE studies are directed to the general enterprise sector. Next, (N = 7, 13%) of the studies were conducted on manufacturing and service enterprises. Also, (N = 4, 7%) studies were conducted in the supply chain sector. Lastly (N = 1, 2%) study was conducted in virtual banking, virtual factory auction, e-commerce enterprises, small and medium-sized enterprises, energy enterprises, facility management, and aircraft enterprises individually.

4.2.Impact of COVID-19 on Enterprises

As at May 2020, the COVID-19 has spread across the world forcing enterprises to change their mode of working to remote workspace (Nagar, 2020). Evidently, enterprises are also impacted by the pandemic, due to its deeply interconnected market to global IT and web applications used in other sectors such as in e-commerce, education, banking, healthcare, supply chain, etc. (Borowski, 2020). The COVID-19 disruption has impacted enterprise process causing a tipping point in creating a new norm for enterprise operations (Borowski, 2020). Positively, the pandemic has resulted in growth of digital businesses, increased revenue for pharmaceutical companies, fitness and training companies also experienced increased in revenue as people now exercise from home. Additionally, companies that provide digital services also benefited from the COVID-19 pandemic (Kude, 2020).

Positively, there is increased in adoption of virtual collaborative systems (Borowski, 2020). Findings from Borowski (2020) revealed that 43% of staffs are currently adopting virtual technologies to support teleworking, telecommuting or remote work. Thus, synchronous and asynchronous communication applications such as Microsoft Teams, Zoom, Microsoft's Visual Studio Live Share, etc. are being used (Blueoptima, 2020; Kude, 2020). Conversely, negative outcomes were experience such that many enterprises have to terminate the contract of their staffs during the pandemic due to reduction in demand of their products and services (Borowski, 2020; Nagar, 2020). Additionally, companies are running on limited operations and

even postponing production or temporarily closing down (Nagar, 2020). This has resulted to shortage of materials and delay in delivery of ordered products and services. Based on the research by Chinese market research organizations, COVID-19 is 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 consoled caused by reduction on hardware production in 2020 impacting software enterprises (Nagar, 2020). Additionally, the pandemic has resulted to sudden cancellation of exhibitions by service industry by tech giants around the globe (Nagar, 2020). Moreover, findings from Borowski (2020) reported that working remotely may affect the psychological, social, and physical strain on staffs with low emotional stability thus reducing productivity during the pandemic due to staffs unsure of the future of their job.

Accordingly, enterprises are deploying flexible strategies that will facilitate remote work functionality for their staffs to sustain virtual working practice. Hence, enterprises are adapting to virtual policies and are also required to maintain productivity amidst the pandemic (Blueoptima, 2020). Consequently, this has resulted to a shift toward enterprise operations causing a change to organization methodologies, to carter for customer-based services (Kude, 2020). Respectively, digitalization of VEs are better adapted to be flexible for staffs in the present pandemic to provide customer-centric goods and services (Blueoptima 2020). But to achieve the digitalization of VEs during the COVID-19 pandemic, there is need to explore the issues and also provide recommendations to practitioners on how to factors that impact VE digitalization and process lifecycle to be adoption during and after the pandemic.

4.3.Types of Enterprise Networks, Overview and Characteristics of VE

4.3.1. Types of Enterprise Networks

In this study, the research scope involves exploring collaborations among independent businesses pooling their core capabilities to form enterprise networks. As suggested by Jagdev and Thoben (2001); Al Hadidi and Baghdadi (2019) there are three main types of collaborations within enterprise networks which comprises of supply chain, extended enterprise, virtual enterprise, and the integrated enterprise as shown in Figure 9.

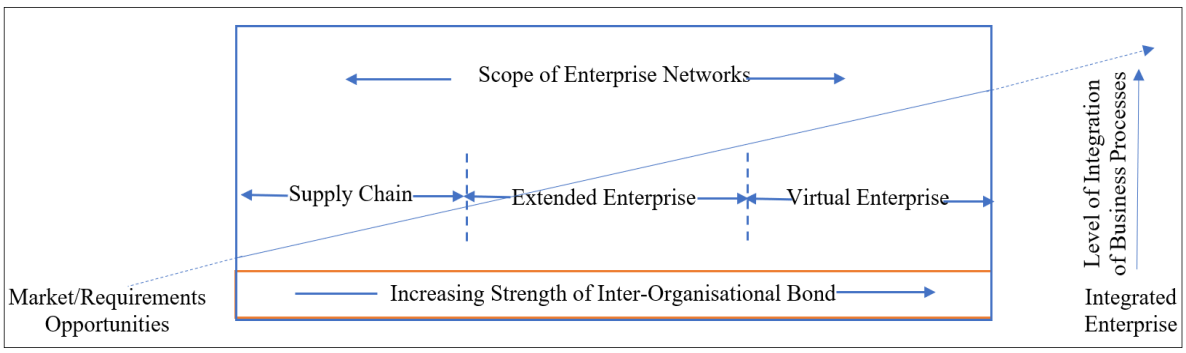

Figure 9 Types of enterprise collaborations adapted from (Jagdev and Thoben, 2001)

Figure 9 attempts to shows the types of collaborations within enterprise networks which are formed based on the market requirements or opportunities and level of integration of business process. Each of the collaborations within enterprise networks are discussed below;

- **Supply Chain**

Supply chain is a set of activities by which several organizations referred to as nodes agreed to contribute their proficiency towards the completion and supply of a shared end-product (Jagdev and Thoben, 2001; Santos-Neto and Costa, 2019). Each node in the network acts as a customer and a supplier (Agrawal et al., 2019). In supply chain a sequence of business activities starts with "Start Activity" and concludes with "End Activity" aimed at achieving the final product to be extended to the customers (Jagdev and Thoben, 2001). In a supply chain, a customer receives or buys an unfinished product from upstream suppliers, uses its core knowledge to add value to the goods and passes or sells them on to next firm (node) downstream in the chain (Jagdev and Thoben, 2001). Supply chain implementation comprises of different requirements that must be achieved, and they include understanding and acceptance of the role by the partners in the supply chain network (Pires et al., 2001). Creating an effective communication chain between different businesses operations processes such as sales, marketing, production, purchasing, and planning (Al Hadidi and Baghdadi, 2019). Lastly, each firm in the chain must adapt to the continuous change of other firms in the network (Seyedghorban et al., 2020).

- **Extended Enterprise**

The concept of extended enterprise has recently been used in businesses to represent high level cooperation between different enterprises (Al Hadidi and Baghdadi, 2019). Extended enterprise refers to two or more organizations that wish to extend their operations to other businesses in order to enhance their competitiveness and increase their existing capabilities (Browne and Zhang, 1999). An example of extended enterprise is the partnership between existing enterprises, where each firm offers one or more services such as transportation service, financial service, or any form of logistics (Al Hadidi and Baghdadi, 2019). These enterprises engaged collaboratively in the development, design, production, and distribution of a product to the customers (Jnr et al., 2020). Extended enterprises aim to achieve reduced cost, deliver product on time, or improved quality (Jagdev and Thoben, 2001; Jnr, 2020).

- **Virtual Enterprise**

VE comprises of geographically distributed independent and temporary nodes that form an electronic communication network of businesses, partners, and competitors ready to grant access to each other market and apply integration over ICT technologies (Al Hadidi and Baghdadi, 2019). VE is one manifestation of logistic response to the globalization and dynamics of today's markets. The baseline for a VE is adjusting to customer needs (Jagdev and Thoben, 2001).

- **Integrated Enterprise**

Integrated enterprise is a type of association which combines virtual and extend enterprises to form a type of collaboration based on the integration and compatibility between the enterprises (Jagdev and Thoben, 2001; Al Hadidi and Baghdadi, 2019). The scope of this current study is to explore the digitalization of VE. Thus, further description of VE is seen in section 4.3.2.

4.3.2. Overview of VE

The concept of VE was first mentioned in 1991 by Byrne who was a Lehigh university's scholar in Agile production (Feng et al., 2007), but was further conceptualized by Byrne in 1993 as the temporary interactions between independent enterprises using ICT (Sadigh et al., 2017). A VE refers to a temporary or permanent collaboration of geographically dispersed organizations which are linked in order to complete a production process (Esposito and Evangelista, 2014).

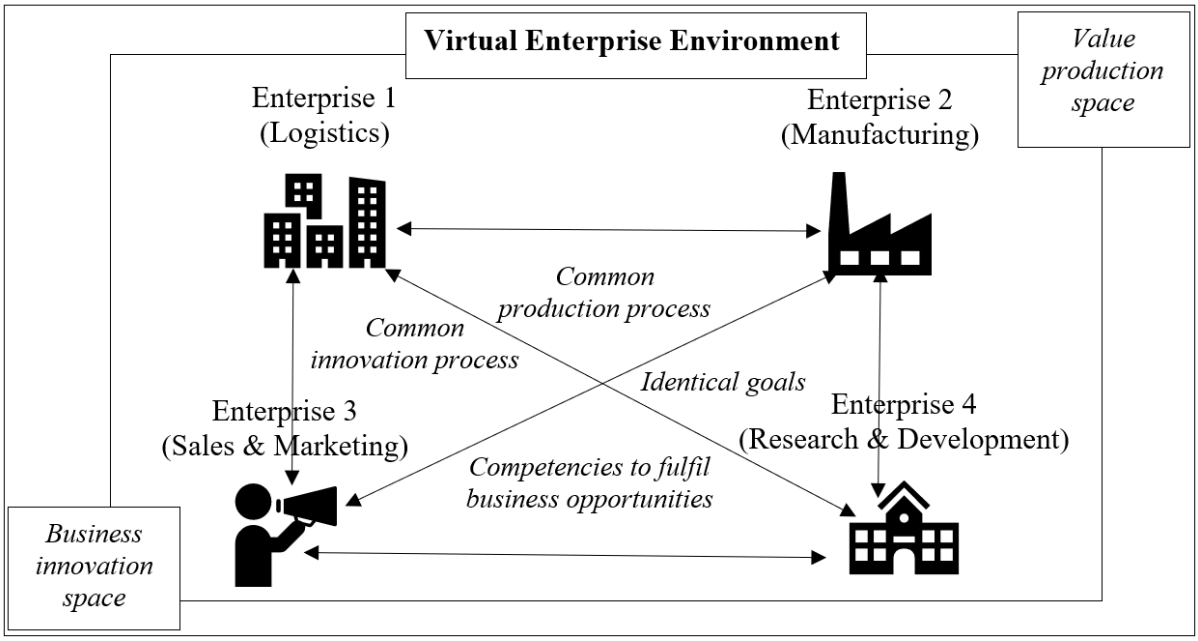

Figure 10 Structure of a typical VE

VEs form a cooperation of legally independent businesses contributing their core competencies as one organization to customers (Grecu and Ghita, 2015; Perez-Castillo et al., 2019). VE involves borderless organizational alliance, that exists virtually (Lefebvre and Lefebvre, 2002; Sadigh et al., 2014). In a VE, several legally independent organizations, establishment or individuals joint together to co-operate for a specific mission as seen in Figure 10. Thus, Figure 10 depicts a structure of a typical VE which comprises of four enterprises as in the example, (but can be more than four enterprise or more) with identical goals, common innovation/production process and competencies to fulfil business opportunities for new business and value creation (Knoke and Eschenbächer, 2012). Thus, in a VE, new business requirements arise, and the individual enterprises often do not have all needed competencies and skills to address these requirements (Camarinha-Matos et al., 2003). By combining their areas of knowledge with the complementary skill of other partner firms, it is possible to create a VE, capable of responding to new requirements (Chen et al., 2011).

The participating organizations share skills, costs and core competencies that support them to access a specific market niche with solutions that could not be individually provided (Camarinha-Matos et al., 2003). Each partner brings to the collaboration their core capabilities relevant to the mission and focusses on those areas where it possesses competitive advantage (Mikhailov, 2002). The VE is established to address a specific market opportunity concurrently and quickly, developing a mutual working environment to use and manage collection of

resources provided by the enterprises (Esposito and Evangelista, 2014). The success of a VE depends on all firms collaborating as a synergetic unit, because each organization brings its core competence or strengths to the consortium (Camarinha-Matos et al., 2003).

4.3.3. Characteristics of VE

To summarise, the key features of a VE can be defined as follows;

- **Focus on main competencies:** Each partner organization contributes with its competence, which is complementary to other businesses' competencies (Al Hadidi and Baghdadi, 2019). This supports partner organizations to meet market demands that individual enterprise would not otherwise have the skills and competencies to fulfil (Chen et al., 2011). Thus, the combination of competencies provides greater flexibility and synergies to meet clients' requirements (Esposito and Evangelista, 2014). Moreover, every partner enterprise contributes to the VE with its own main competencies, in so doing facilitates service and product excellence (Pires et al., 2001).
- **Opportunity-driven:** A VE is a temporary collaboration prompted by business opportunity. The contributing organizations work together to a provide specific opportunity (Sadigh et al., 2014; Grecu and Ghita, 2015). A significant characteristic of a VE is the potential for innovation which supports co-operating enterprises to respond efficiently and rapidly to specific market demand (Pires et al., 2001).
- **Dynamic structure:** VE's are highly dynamic and their life cycles may be very short (Brahimi, 2019). The dynamic organizational structure of VEs is based on their adaptable rules which render it flexible for participating enterprises to leave or join the consortium. All the consortium members have the same rights where there is no main leader (Camarinha-Matos et al., 2003).
- **Semi-stable relationship:** In a VE, a less formal and permanent relationships of requirement are formed among the partners, such that they can survive in the market (Pires et al., 2001; Chen et al., 2011).
- **Trust:** VE are characterized by the degree of trust among members (Grecu and Ghita, 2015). The development of trust is based on partners intention of sharing information, risks and skills (Mikhailov, 2002), which render partners to be more interdependent, demanding greater degree of trust between them (Pires et al., 2001).
- **Technological infrastructure**: This helps enterprises that are geographically dispersed from each other combine their resources and work jointly (Camarinha-Matos et al., 2003). In addition to the distant boundaries between the enterprises, technological infrastructures help to reduce transaction costs (Pires et al., 2001).
- **Virtuality:** VE are based on the deployment of ICT which enables distant enterprises to connect to each other virtually to achieve business goal (Mikhailov, 2002; Esposito and Evangelista, 2014).
- **Flexibility:** VE have strategic objectives to increase adaptability and flexibility to environmental changes (Brahimi, 2019).
- **Autonomy:** VEs can determine their own goals and make their own decisions, independent of the individual organizations' (Esposito and Evangelista, 2014).

- **Immobility and heterogeneity:** these abilities constitute the cornerstone of VEs' success because they reflect diversity of businesses which own different skills, information, and knowledge required for new market opportunities (Brahimi, 2019).

Table 2 shows a comparison between supply chain. The findings suggest that VE are different from supply chain enterprise in terms of their aim, structure, collaboration approach, duration, involvement, life cycle, innovative speed, norm, market requirement, and demand

Table 2 Comparison of supply chain and VE adapted from (Pires et al., 2001)

Aspects	Supply chain	Virtual enterprise
Main aim	Improve competitiveness within product value chain.	Exploit existing business opportunities.
Enterprise structure	Mostly comprises of stable enterprise.	Comprises of a temporary and dynamic network.
Collaboration	Usually involves large firms that co-ordinates in the partnership.	All consortium members participate equally in making decisions.
Period	Long-term enterprise cooperation grounded on contracts.	Temporary network for a specific business opportunity.
Involvement	An organization can participate in different networks, but exclusiveness may also occur.	An organization can participate in many VEs at any point in time.
Product life cycle appropriateness	Throughout the product life cycle.	Focus a lot on the creation phase.
Speed of firm innovation	Usually found in stable and traditional industries.	Most appropriate for innovation based industries.
Competitive norms	Based mostly on service level, quality, and lead time.	Based on quality, lead time, and cost.
Market criteria	Cost oriented.	Service level based.
Key demand features	Are mostly predictable and it is required as a medium to forecast sales.	Are volatile and usually based on market needs.

Furthermore, Table 3 shows a comparison between extended enterprise and VE highlighting the key features of extended enterprise and VE in terms of goal, purpose, stability, partner relationships, boundaries, type, co-ordination of alliance, and ICT deployment.

Table 3 Comparison of extended enterprise and VE adapted from (Browne and Zhang, 1999)

Aspects	Extended enterprise	Virtual enterprise
Strategic goal	Stronger long term goals.	Stronger short-term goals.
Collaboration purpose	Long-term business co-operation.	Temporary co-operation for products or projects.
Enterprise stability	Stable organization of businesses within the product value chain.	Dynamic organization of firms with core competences.
Partner relationships	Mutual dependence and trust for long term.	Temporary but dynamic.
Boundaries	Full formed for long term.	Partly formed for short term.
Business type	Product based on value-chain.	Based on frequent project or niche market.
Co-ordination of alliance	The manufacturer mostly manages the partnership.	Frequently the consortium members manage the co-operation.
ICT deployment	Enabled and facilitated by ICT.	Operation mainly depends on modern ICT.

4.4.Digital Innovations Employed in Virtual Enterprises During COVID-19 Pandemic

4.4.1. Benefits of Digitalization of VE During COVID-19 Pandemic

Businesses are looking for ways to survive during the COVID-19 pandemic while increasing productivity and reducing cost (Liu et al., 2011; Verhoef et al., 2019), is the challenge VEs are facing due to COVID-19. The digitalization concept comes as a new hope for businesses to remain competitive in COVID-19 era. It involves transforming key enterprise activities to exploit and integrate digital technologies (El Hilali and El Manouar, 2018b; Kempegowda and Chaczko, 2018; Vail, 2019). Digitalization in VEs refers to an environment where organizations develop "digital imperatives" based on the application of digital capabilities to products, processes, and assets towards improving efficiency, increasing customer value, managing risk, and uncovering new monetization opportunities (Sari et al., 2007).

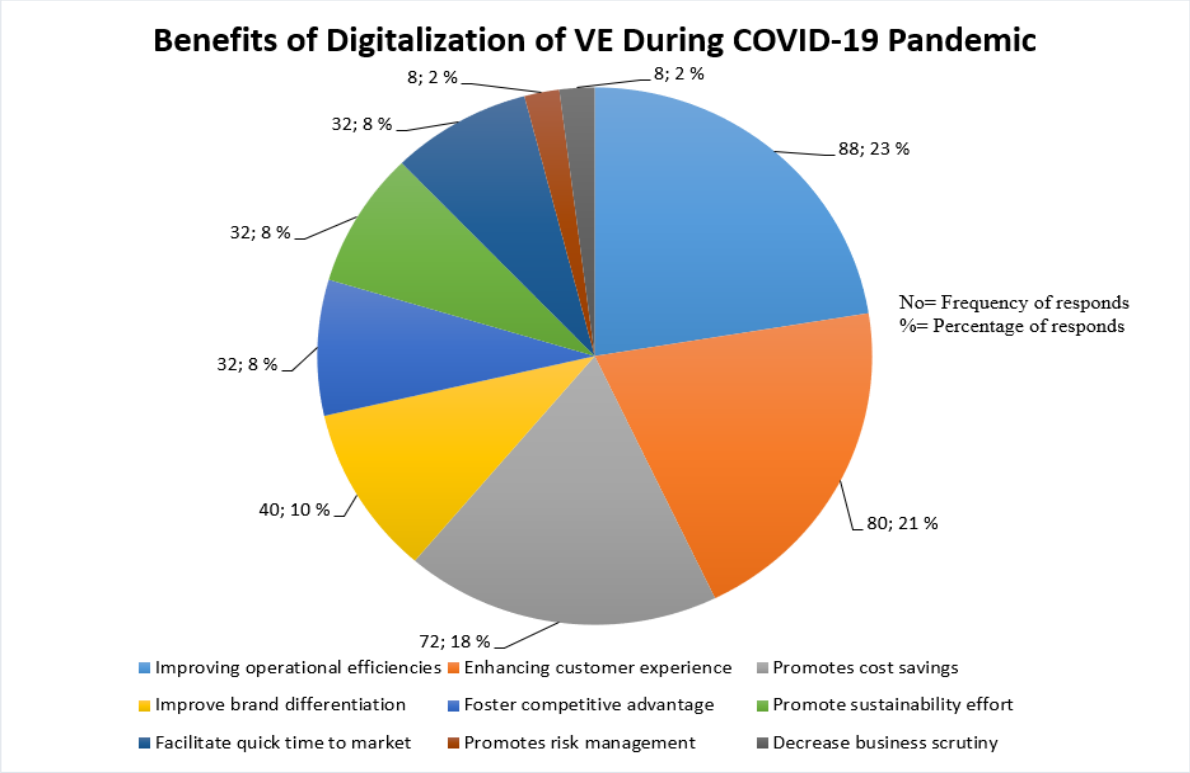

Figure 11 Benefits of VE digitalization during COVID-19 pandemic

Findings from a survey conducted by El Hilali and El Manouar (2018a) reveal that the benefits of VE digitalization, as seen in Figure 11, comprise of approximately (N = 88, 23%) in improving operational efficiencies, (N = 80, 21%) in enhancing customer experience. Also, the result suggests (N = 72, 18%) towards promoting cost savings, (N = 40, 10%) in improving brand differentiation, (N = 32, 8%) in fostering competitive advantage, promoting sustainability effort and facilitating quick time to market individually. Lastly, (N = 8, 2%) in promoting risk management and decreasing business scrutiny respectively. Hence, digitalization is not only about digital transformation of existing processes, it about utilizing digital capabilities (such as cloud native applications, real-time data, etc.) (Kim et al., 2006), to discover new business opportunities in transforming VEs from manufacturing companies to a digital business that revolutionized many industries (El Hilali and El Manouar, 2018b).

VEs deploy digitalization for increasing their capabilities and achieving sustainable business process to reduce costs and improve operational efficiency. VEs can also digitalize services for better use of their core competencies by effective communication within the consortium for improved resource sharing and ultimately creation of value added services to clients (Javed and Yasir, 2019). Thus, digitalization is a driver to survival during and after the COVID-19 pandemic (Zangiacomi et al., 2020). Digitalization has become a medium to help businesses achieve increased sales and competitive positions, better customer service, and business development (Agrawal et al., 2019; Verhoef et al., 2019).

4.5.Current Digital Innovations Employed in VE During COVID-19 Pandemic

Digitalization in VEs is not only about digitalizing existing business processes, it is about using digital capabilities or disruptive technologies to create and capture new value. Figure 12 shows the disruptive technologies adopted in VE digitalization during the COVID-19 pandemic.

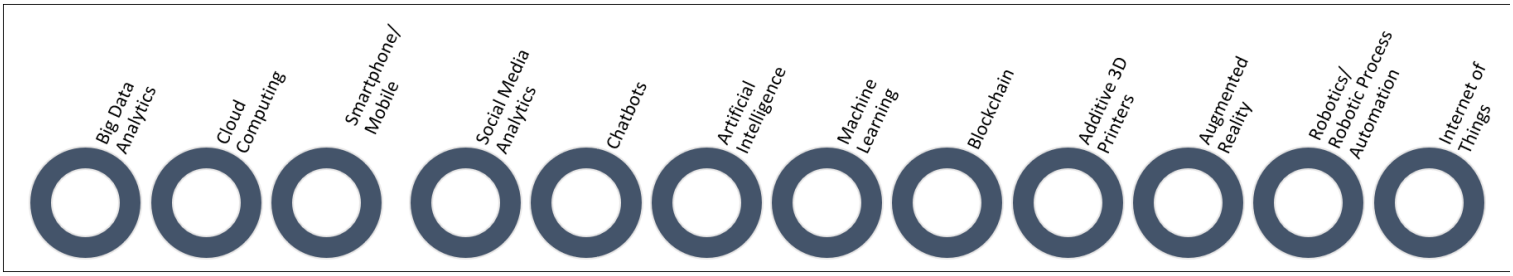

Figure 12 Disruptive technologies in VE digitalization

Each of the disruptive technologies in VE digitalization are discussed in Table 4;

Table 4 Disruptive technologies employed in VE digitalization during COVID-19 pandemic

Disruptive technologies	Description in the context of VE digitalization	Sources
Internet of Things (IoT)	IoT is a technology based on data transfer across object or devices over internet. It comprises of inter-connected devices such as sensors, smartphones, wearable devices, etc. IoT helps to gather information or to create an activity by improving operativeness, reduce time and increase viability for businesses. IoT devices uses an Internet Protocol (IP) address for internet connectivity allowing businesses to receive and send data, with other systems and network devices. Data from IoT devices are use in VEs for real-time monitoring, decision making, and business process optimization.	(Kempegowda and Chaczko, 2018; Barbosa et al., 2019; Ulas, 2019).
Cloud computing	Involves internet based information services that provides cloud storage sources which are used or shared between partners. It enables rapid deployment of cloud based services that provides sufficient computing power to enterprises. Currently, cloud computing ensures that software applications such as Microsoft Office and logistics programs, can be used directly from web browsers instead of downloading and installing on a local computer. Cloud computing supports processing and storage of business files and documents, which are personally stored on the computers of partners instead of data centers. This enables businesses to access computer files remotely through the internet. Cloud solutions offer flexibility, scalability, and an opportunity to decrease costs such as assets expenditure for servers and hardware replacement and maintenance costs, security and IT support costs.	(El Hilali and El Manouar, 2018b; Kempegowda and Chaczko, 2018; Barbosa et al., 2019; Ulas, 2019).
Big Data analytics	Big data is data which a computer is unable to process. Big Data involves any large amount of unstructured, structured, or semi-structured data that has the possibility to be processed and analyzed for information. Analytics from Big Data can help businesses to derive decisive customer needs to provide value added services. Big Data analytics provide opportunities for VEs, by enabling a better understanding of business operations within the consortium, the needs of customers and partners, and the complete business environment. In VEs, Big Data can be generated from social media, mobile and IoT devices to provide insights.	(El Hilali and El Manouar, 2018a; Kempegowda and Chaczko, 2018; Barbosa et al., 2019; Ulas, 2019).

Machine learning	Involves combining data collected from internal sources (sensors and other devices), private, and public (public administration) to be used by computer algorithms such as deep learning, learning vector quantization, least-angle regression, etc. for preventive identification of problems, forecasting and recommendations, such as in logistics, product life cycle and transportation, among other possibilities.	(Barbosa et al., 2019).
Smartphones/Mobile	Enables partner to communicate via 3G, 4G, 5G powered by smartphone that use internet during business operations. Approximately 1 billion phones are sold worldwide every year. Use of smartphones in business provide revenue stream for VEs to market products, discover new opportunities from data produced from smart phones.	(Kempegowda and Chaczko, 2018; Ulas, 2019).
Social Media Analytics	VEs can use social media such as Facebook, Twitter, Histogram, etc. to develop analytics that can be used to understand client's needs and expectation. Also, enterprises can use social media to communicate products and free services in real-time and share product information, enterprise activities, upcoming products, or for advertisement. Data generated from social media can be used in VEs as an opportunity for profiling customer's behaviour and their purchase patterns, altering the business model employed by companies.	(Kempegowda and Chaczko, 2018; El Hilali and El Manouar, 2018a; Vial, 2019).
Artificial Intelligence (AI)	Involves intelligence demonstrated by machines similar to natural knowledge of human beings and can provide insights of business process improvements that are not possible by human intervention. AI examines how human brain reasons and how humans learn and choose as they attempt to solve a problem, and it imitates the solution. AI does not act upon the developers' mind, instead it learns, understands and judges itself. In most VEs, manufacturing is carried out by robots using AI without human involvement. These robots perform manufacturing tasks and are in constant learning and improvement.	(Jr et al., 2017; Kempegowda and Chaczko, 2018; Ulas, 2019).
Blockchain	Is referred to as a decentralized ciphering record book. It supports Bitcoin, which is a digital currency supported generally and has not been controlled by a single entity since 2012 until today. It employs distributed database technology which provides encrypted process follow-up. Blockchain involves a digital, decentralized distributed ledger with business transactions recorded chronologically to enable openness, minimizing the cost of digitization operations. Blockchain forms a foundational technology provides transparency in business transactions.	(Kempegowda and Chaczko, 2018; Ulas, 2019).
Robotics/Robotic Process Automation (RPA)	Robotics involves using Robots with intelligence and ability to automate tasks, thus reducing labor costs. Likewise, RPA are specialized software programs that manages and controls repeatable business process in place of humans. RPA provides a critical organization-wide approach to decrease recurring tedious tasks towards increasing service efficiency and cost reduction. Robots possess greater flexibility and shorten delivery time for goods and products to the market. Robotics shift the capital/labour mix while managing societal expectations. Thus, most VEs are rapidly deploying robots for manufacturing purposes to increase the quality of products and decrease manufacturing costs.	(Kempegowda and Chaczko, 2018; Ulas, 2019).
Additive 3D Printers	3 Dimension (3D) also known as additive manufacturing refers to various processes employed to synthesize 3 dimensional objects. It also involves 3D printing where manufacturing is done utilizing computer-aided design for prototyping parts of larger systems components. Additive 3D printers involve devices that quickly produce models which are designed on a computer or prepared in 3D by using various materials without any fixture or mould. 3D helps to lower cost of product design and manufacturing industries. 3D manufacturing is faster and can be utilized in product design, minimizing mould cost, prothesis, plastic plasters, medical applications, robot design, and model making.	(Kempegowda and Chaczko, 2018; Ulas, 2019).
Chatbots	Chatbots refers to software applications which are developed with the intent of backing up users in service sectors such as in customer service or advertising to imitate written or verbal human words/speaking. VEs uses AI such as Google assistant, Alexa or Siri as examples of advanced chatbot.	(Ulas, 2019).
Augmented Reality (AR)	AR is defined as the extension of physical reality by integrating layers of computer produced information into the real environment. Information in AR could be any kind of virtual content or object, including text, sound, graphics, haptic feedback, video, Global Positioning Systems (GPS) data, and possibly smell. AR use in enterprise can ensure increase in productivity and a reduction in costs when used in manufacturing processes by providing a virtual interactive experience of real-business world environment that assists enterprises in decision making. With the deployment of advanced AR technologies (e.g., adding object recognition and computer vision), the information about the surrounding real world of the customers becomes interactive. AR technology can be applied for product markets to conduct visits to fully digital products offered by VE.	(Kempegowda and Chaczko, 2018; Ulas, 2019).

4.6.Factors that Influence Digitalization of VEs During COVID-19 Pandemic

Findings from Grab and Ilie (2019) as seen in Figure 13 show the factors that promote VE digitalization suggesting that great technology partners accounts for 51.6 %, company culture influences 49.8 %, and support from managers is based on 49.5 %. Also, knowledgeable employees determine 48.2 %, adequate budget allocation drives 39.7 %, relies on senior leadership's vision influences 39.5 % and 4.7 % are based on other issues within the enterprise.

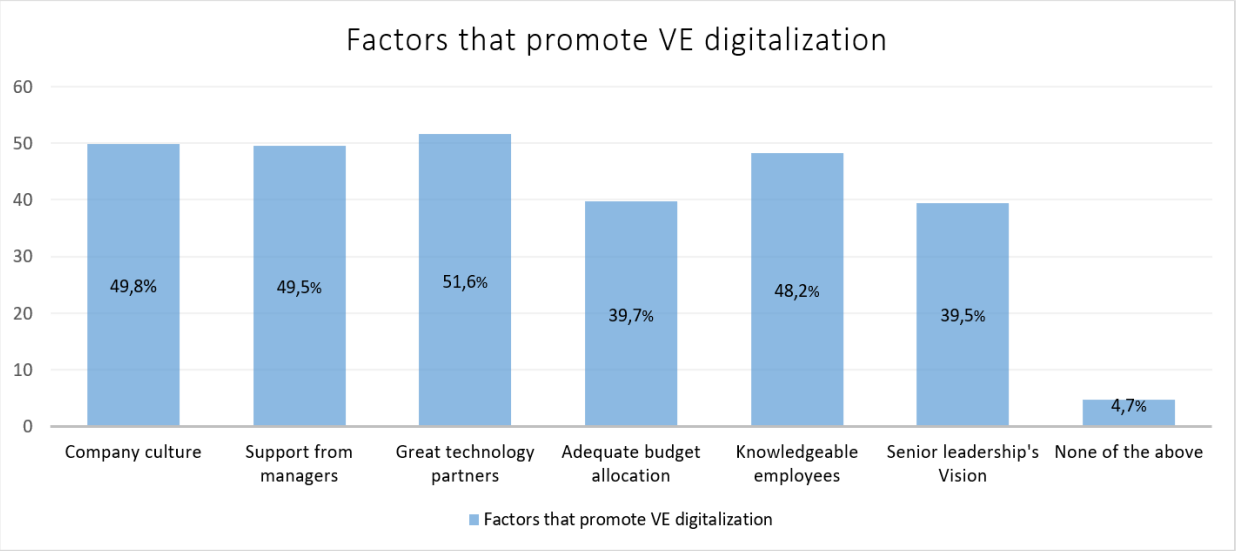

Figure 13 Factors that promote VE digitalization

Irrespective of these findings, little is known regarding the factors that inhibits or acts as barriers against VE digitalization during the COVID-19 pandemic. According to Agrawal et al. (2019), a few organizations have recognized the need to digitalize business operations, but only 5 % have successfully digitized enterprise activities due to factors that inhibits enterprise digitalization. Evidence from the literature indicated that "human resource is the key barrier to business digitalization" (Jr et al., 2017; Agrawal et al., 2019). This is because the lack of digital strategies in enterprise and a lack of sense of urgency. Based on a review of the literature 12 factors that impacts VE digitalization during the COVID-19 pandemic have been identified. A brief description of these factors is given below;

4.6.1. Inadequate Sense of Urgency

One of the inhibitors of VE digitalization is the lack of urgency towards digital transformation. Urgency in the context of digitalization involves businesses having initiatives to utilize digital services to increase organization's profit (Agrawal et al., 2019). VE digitalization aids in addressing existing economic issues but the attitude of partners is a barrier to complete digitalization. Hence, it is required for VEs to create strategies that creates a real sense of urgency during the COVID-19 pandemic (Grecu and Ghita, 2015).

4.6.2. Current Organizational Structure

The structure of the enterprise comprises the strategies employed by executives to allocate and maintain activities within the VE. It comprises the connections which links all staffs based on

their responsibilities and roles (Camarinha-Matos and Afsarmanesh, 1999). The enterprise structure helps to create and manage a pathway for communication among VE partners (Agrawal et al., 2019). Thus, organizational structure for a VE should be agile to allow for knowledge dissemination within the consortium amid the COVID-19 pandemic.

4.6.3. Inadequate Strategic Alignment

The strategic alignment of enterprise support in deploying ideas into a model for digitalization of VE operations (Grecu and Ghita, 2015). For a successful VE digitalization initiative, the involved enterprises should specify various strategic directions geared towards technological innovation for customers (Camarinha-Matos and Afsarmanesh, 1999; Agrawal et al., 2019). The plan for VE digitalization should be client based thereby promoting smart automation (Agrawal et al., 2019). The VE strategies should include an understanding of markets opportunities and customer's needs during crises (Grecu and Ghita, 2015; Agrawal et al., 2019).

4.6.4. Rigid Business Processes

In digitalization of VEs, current business design model should be optimized for digital operations so that quality goods can be produced in time (Brahimi, 2019). Nodaway's changing customer demands impact VE. Hence, the product life cycle should be shorten (Camarinha-Matos and Afsarmanesh, 1999; Agrawal et al., 2019). VE processes need to be flexible and agile to cater for different customer expectations during the COVID-19 pandemic.

4.6.5. Disassociated Corporate Goals

Alterations in enterprise visions creates barriers to VE digitalization. Hence, businesses are focused on decreasing time and costs, whereas client lead approach, flexibility, scalability, innovation, etc., impacts enterprise operations (Agrawal et al., 2019).

4.6.6. Failure to Meet Up with Corporate Targets

Currently, VEs are digitalizing their business operations by adopting new digital services and products (Grecu and Ghita, 2015). However, existing VEs' activities are not robust to promote corporate dynamism (Agrawal et al., 2019). There is need for cultural and tectonic change in enterprise activities performed by partners within the consortium (Camarinha-Matos and Afsarmanesh, 1999; Agrawal et al., 2019), during the COVID-19 pandemic.

4.6.7. Unforeseen Enterprise Risk

Digitalization links business partners, streamline enterprise operations, improving businesses and strengthening customer relationships (Putnik and Cruz-Cunha, 2013; Verhoef et al., 2019). Although, VE digitalization requires high execution cost and associated risk that can surface during business transformations that limits Return on Investment (ROI) (Agrawal et al., 2019).

4.6.8. Inadequate Industrial Guidelines

The unavailability of guidelines impact VE digitalization (Agrawal et al., 2019). Thus, VEs are limited in foresight as regards to which enterprise sectors to digitalize to improve existing

business models (Sari et al., 2007). Therefore, there is need for a reference model for VE digitalization amidst the COVID-19 pandemic (Zangiacomi et al., 2020).

4.6.9. High Deployment and Operational Cost

Funding is needed to improve raw materials and resources, new organizational capabilities and skilled workforce (Agrawal et al., 2019). Thus, training of VEs employees is important to improve enterprise digitalization initiatives (Esposito and Evangelista, 2014). VEs need to make a cost benefit analysis as regards to deployment and usage cost (Sari et al., 2007).

4.6.10. Inadequate Management Dedication

Inadequate management commitment is an important factor for effective VE digitalization (Agrawal et al., 2019). Support from top management provides a clear vision and value towards digitalization of enterprise operations (Jnr, 2020). Without management involvement employees will not be dedicated, particularly elder personnel, who are less conversant with digitalization (Javed and Yasir, 2019; Jnr et al., 2020). Thus, management should provide resources to promote VE digitalization (Grecu and Ghita, 2015).

4.6.11. Limited Skill and Knowledge Required

Digitalization of VEs requires the workforce to be involvement (Agrawal et al., 2019). Also, employees need to have the skillset required to work in a digitalized working environment. But, findings from the literature (Kim et al., 2006) suggest that VE workforce possess low knowledge on digitalization. Digital innovation requires staffs with a digital skill, proficient of using digital solutions and technologies (Jnr et al., 2020). Thus, this lack of aptitude does slow VE digitalization (Camarinha-Matos et al., 2000).

4.6.12. Concern of Private Information Loss

Privacy and security are one of the main barriers impacting VE digitalization (Jnr, 2020). Presently, organizations are connected digitally, and this may create an avenue for hacker to attack and cause large disruptions raising the importance of cyber security measures (Zangiacomi et al., 2020). Thus, security should be improved during the COVID-19 pandemic.

4.7.Qualitative Review of Prior Studies

This sub-section aims to present prior VE studies that proposed approaches related to digitalization of VE business operations as seen in Table 5;

Table 5 Qualitative review of prior studies

Authors/ Contribution	Focus Area in VE	Clustered VE Lifecycles	Method	Location
Brahimi (2019) suggested an agents' model based on ontologies and web services for creating and managing VE.	Aimed to decrease high costs incurred and improve flexibility with the use of technology in VE selection and negotiation.	Creation, operation, evolution, and dissolution.	Conceptual	Algeria
Mahmood et al. (2018) developed a risk assessment method for VE of small and medium sized businesses.	Provided a method to evaluate and mitigate risks related to the action phase of a VE.	Realization, formation, action, and closure.	Conceptual	Estonia

Ferreira et al. (2017) suggested a meta-enterprise approach for VE integration management.	Aimed to provide an approach for VE lifecycle alignment managed using project management guidelines.	Identify opportunity, initiation, design/integration, operation, and dissolution.	Literature review	Portugal
Sadigh et al. (2017) developed an ontology-based multi-agent VE system.	Improved VE operations in order to support systems integration and flexibility.	Creation, formation, design, operation, and dissolution.	Experimental	Turkey
Sadigh et al. (2014) suggested a multi-agent model for partner selection phase in VE.	Presented an ontology model to maintain and store dynamic VE data in partner selection phase.	Creation, formation, design, operation, and dissolution.	Experimental/ Simulation	Turkey
Romero and Molina (2011) proposed a green VE reference framework for breeding environment.	Provided a clear method for deploying sustainable and fully flexible reverse and forward supply networks.	Creation, operation, metamorphosis, and dissolution.	Conceptual	Mexico
Cong et al. (2010) presented an integrated model for service-based VE information system.	Aimed to achieve dynamic reconstruction, integration, openness, reliability, and safety.	Recognition, formation, operation, and termination.	Conceptual	China
Ding and An (2009) investigated emission decrease and energy conversation based on the life cycle of VE.	Presented an integrated energy saving and lessening management model of VE.	Formation, operation, evolution, and termination.	Conceptual	China
Feng et al. (2007) investigated the integrated quality management in VE life cycle.	Describes initiatives to be deployed to improve quality management in VE.	Formation, operation, evolution, and termination	Conceptual	China
Sari et al. (2007) explored the formation of dynamic VE and enterprise networks.	Mainly focused to develop a methodology for VE.	Creation, operation, dissolution, and demand.	Case study	Turkey
Amato Neto (2006) investigated the deployment of VE in an aircraft company in relation to impact competitiveness.	Identified some organizational and technical problems and solutions in VE implementation.	New opportunity, search partner, recruiting, VE, operation, and breakup.	Case study	Brazil
Kim et al. (2006) developed a modeling framework for interoperable and agile VE.	Offered a comprehensive solution to facilitate effective communication of stakeholders.	Business opportunity, identify partner, configuration, operation, evolution, and dissolution.	Meta-modelling	South Korea
Carvalho et al. (2005) proposed the concept of autonomous production system in VEs.	Aimed to support units upon which firms can be built and maintained to better address globalization issues.	Formation, operation, recontinuation, and dissolution.	Conceptual	Portugal
Camarinha-Matos et al. (2003) proposed an approach for agile VE development.	Identified the requirements for achieving agility support in VE life cycle.	Creation, operation, evolution, and dissolution.	Conceptual	Portugal, The Netherlands, and Brazil
Kwon et al. (2003) provided a redefining concept for VEs.	Presented the characteristics of a VE based on new definition.	Identification, formation, design, operation, and dissolution.	Conceptual	South Korea
Mikhailov (2002) implemented a fuzzy analytical method for partnership selection in VE formation.	Justified that partnership selection in VEs should be based on a multiple criteria decision-making method.	Identification, formation, design, operation, and dissolution.	Experimental	United Kingdom
Pires et al. (2001) presented a comparisons and migration of supply chain and VE.	Discusses how co-operative firms, idealized to work as a VE, and acquires features of a supply chain structure.	Creation, operation, continuation/re-continuation, and dissolution,	Case study	Brazil
Petersen et al. (2001) developed an agent-based method to modelling VEs.	Supported cooperative work within distributed entities using agents to provide distributed working environments throughout a VE's life cycle.	Identification, concept, requirement, design, implementation, operation, and decommissioning.	Modelling	Norway

Camarinha-Matos et al. (2000) defined how to support agility in VEs.	Specified various requirements and methods for achieving agility during VE life cycle.	Creation/configuration, operation, and dissolution.	Conceptual	Portugal, The Netherlands, Brazil
Camarinha-Matos and Afsarmanesh (1999) provided general requirements and tendencies for VEs.	Provided general functional requirements for various phases of VE's life cycle.	Creation/configuration, operation, and dissolution.	Conceptual	Portugal and The Netherlands
Rocha and Oliveira (1999) presented an e-market architecture for VE creation.	Focused to provide a multi-criteria negotiation protocol for VE creation.	Identification of needs, partner selection, operation, and dissolution.	Conceptual	Portugal

In Table 5, the characteristics of prior scholarly works are reviewed based on the contribution, aims, identified life cycles, method and location. Further, the digitalization of VE life cycles comprises of six clustered phases (identify opportunity, VE creation, operation, configuration/re-configuration, evolution, and dissolution) derived from the literature.

4.8.Functional Requirements for VE's Life Cycle

The life cycle of VE is in many ways similar to the life cycle of a standard enterprise project (Carvalho et al., 2005). Similarly, as recommended by Kim et al. (2006), the VE life cycle possibly has strong relationships with the creation and ending of the value chains grounded on business processes. Accordingly, this sub-section aims to identify the general functional requirements for the various phases of a VE's life cycle. Based on findings from Table 5, Figure 14 depicts the derived clustered digitalization of VE's life cycles where the VE evolves through various stages.

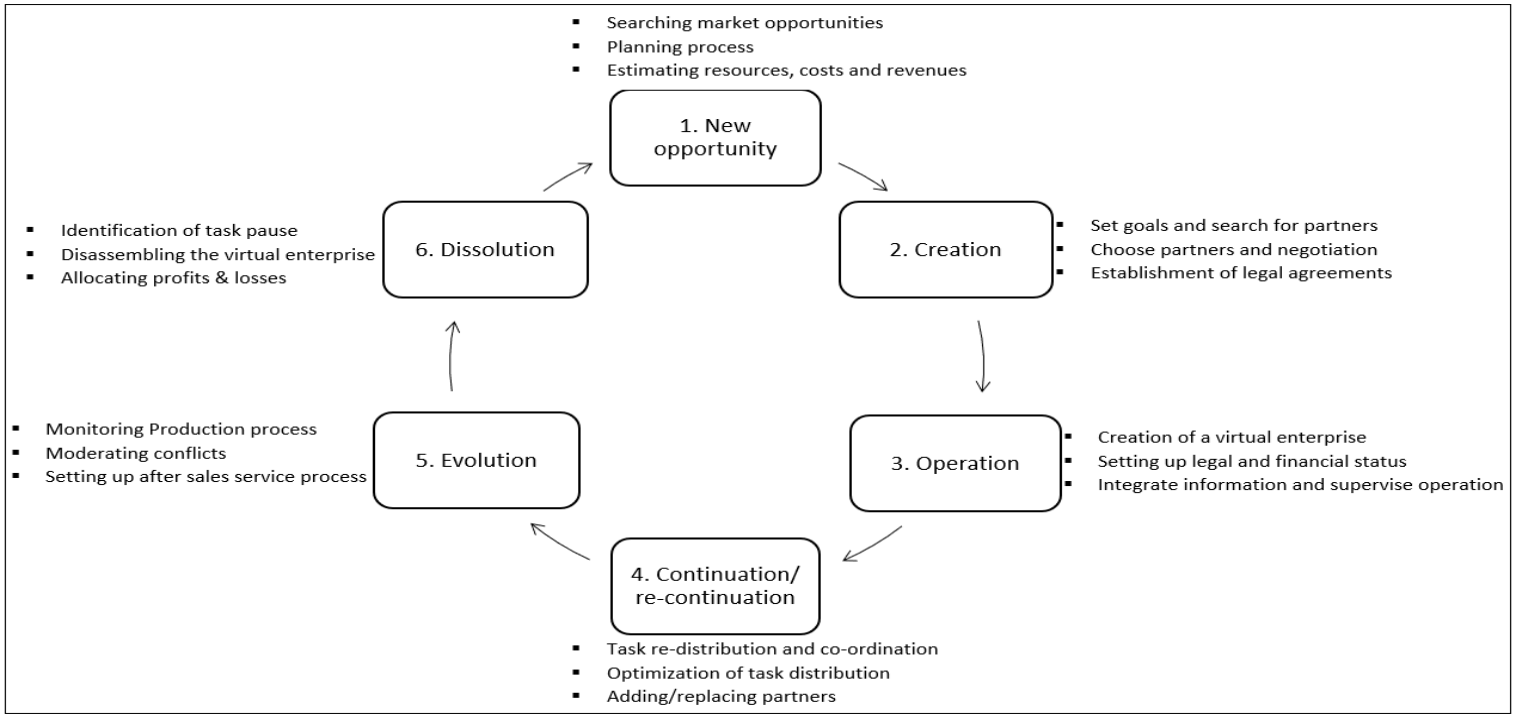

Figure 14 Lifecycle of a typical digitalization of VE

Figure 14 depicts the derived clustered digitalization of VE lifecycles and functional requirements, each of which are elaborated in detail below;

4.8.1. Identify Opportunity

This is the first phase of VE life cycle which entails opening new business fields and identifying business opportunities through market analysis (Kim et al., 2006). In this phase, a lead enterprise which already has information about the core skills of other firms, tries to find a profitable market opportunity (Mikhailov, 2002; Mahmood et al., 2018). The opportunity is practicable and feasible in terms of the VE's competencies (Rocha and Oliveira, 1999). Once an opportunity is found, the enterprise plans the production process and estimates the revenues and costs obtainable from the new opportunity (Sari et al., 2007; Kwon et al., 2013). A VE starts its activity by establishing mutual agreements among its partners on issues such as intellectual property rights, procedures, common standards, and ICT integration (Mahmood et al., 2018). The VE seeks out and await customer demands, and when precise customer demands are identified, the business potential is formed by establishing a VE (Petersen et al., 2001; Tølle et al., 2002; Lomas et al., 2007).

4.8.2. Creation

This is the second phase which involves choosing participating members to form a VE (Kwon et al., 2013; Mahmood et al., 2018). Generally, the creation phase aims to form a group of firms to carry out business operation (Mikhailov, 2002; Brahimi, 2019). Once new business opportunity is identified, there is need to plan a suitable VE, identify partners and establish cooperation agreements (Romero and Molina, 2011; Brahimi, 2019). During this phase, several iterations are performed to find the most suitable enterprises for the particular business opportunity that has been identified (Carvalho et al., 2005). The individual enterprises (partners) are rationally selected based on their specific resources, availability, knowledge, costs, and skill (Rocha and Oliveira, 1999; Mikhailov, 2002), to provide a solution to specific customer needs (Sari et al., 2007). The main activities carried out during this phase includes;

- Search for partners: this activity involves publishing a notice of the requirement specifications based on the enterprise's needs, comprising of all information (quality, technical aspects, human resource, etc.), as well as the research and choice of partners who meet the requirements stated in the announcement (Camarinha-Matos et al., 2000; Brahimi, 2019).
- Negotiation: This process can be employed to select partners, within an agreed duration, specified quality and an agreed price with well-defined and clear objectives (Brahimi, 2019).
- Establishment of legal agreements: The concept of VE does not change the need to legalize business agreements. Thus, contracts are duly signed and legalized by the consortium partners (Camarinha-Matos et al., 2000).

4.8.3. Operation

In the third phase, specific production tasks are assigned to consortium members, based on the project production process plan set up in the initial phase (Kim et al., 2006). This phase also involves co-ordination of information and production flow to start the running of VE operations (Kwon et al., 2013). Once the VE has been configured and set up, it becomes functional and

starts work to realize customer needs (Sari et al., 2007). Depending on the domain, operations may include design, construction, production, and after-sales services (Camarinha-Matos et al., 2000; Romero and Molina, 2011). Findings from a recent study, Mahmood et al. (2018) revealed that the operation phase comprises of the coordination and distribution of tasks, performance monitoring, cost control, and credit management. During operation phase partners schedules and synchronizes operational plans (Mikhailov, 2002), and responsibilities are assigned to each individual enterprise. The successful attainment of mutual goal delivery of the final product to clients depends on the timely operation of each VE member (Camarinha-Matos et al., 2000; Carvalho et al., 2005).

4.8.4. Configuration/Reconfiguration

During the operation of a VE, it might be required to change the roles of some partners or change some partners in the consortium (Camarinha-Matos et al., 2000; Ferreira et al., 2017). As suggested by Carvalho et al. (2005), in this phase, the VE produces batches of products as planned, while the VE is operating, producing services or goods, it is continuously monitored, and its performance is assessed. If the performance level does not meet the requirements specified by the VE members, the VE production process must be reconfigured (Carvalho et al., 2005; Cong et al., 2010). These configuration or reconfiguration means a redesign of the VE based on change of customer needs (Rocha and Oliveira, 1999; Kwon et al., 2013). Moreover, there is a need to allow for easy configuration of enterprise operations for easy agility in order to cope with the diversity of enterprise systems for information visibility and data access rights within the consortium (Camarinha-Matos et al., 2000).

4.8.5. Evolution

This phase involves the re-defining of the VE business models to be more efficient depending on the VE ecosystems (Romero and Molina, 2011), internal situations or business environment. By means of optimization or re-designing of the value chains, the business processes, the business partners, or the business scenarios (Kim et al., 2006). Evolution enables the businesses to adapt their business processes, structure, and strategies to tactically respond to new sustainable market trends and changes (Romero and Molina, 2011). The main activities employed during this phase entails business process management to ensure the attainment of VE's goal(s) to be able to deal with disruptions and may also involve the inclusion or removal of partners from the VE (Brahimi, 2019).

4.8.6. Dissolution

When the market of the service or product declines, then the VE gradually dissolves, allowing members to find new missions to pursue new opportunities (Mikhailov, 2002). Hence, dissolution involves ending the production of business processes based on a lack or vanishing of business opportunity (Mikhailov, 2002; Kim et al., 2006). This phase starts when the VE finishes the execution of its business process. The objective here is to end the created VE (Brahimi, 2019), terminate contracts (Romero and Molina, 2011), and submit a feedback report to the consortium members (Mahmood et al., 2018). This phase also involves delivery of products to clients, processing of paperwork and payments (Sari et al., 2007), distribution of

profits and storage of appropriate information (Rocha and Oliveira, 1999). Lastly, the dissolution phase involves documentation and distribution of data and related information to partners and arrange for customer support and after-sale services (Mikhailov, 2002; Kwon et al., 2013). Accordingly, Table 6 shows the general functional requirements for the various phases of digitalization of VE's life cycle.

Table 6. General functional requirements

Life cycle	Functional requirements	Sources
Identify opportunity	• Identify new market opportunity. • Evaluate new market opportunity. • Determine project mission. • Identify customers' requirements. • Identify potential industry sectors. • Identify infrastructures and support services. • Market information recognition. • Estimate revenues of a potential new venture. • Estimate necessary skills and competencies.	(Camarinha-Matos et al. 2000; Mikhailov, 2002; Feng et al., 2007; Sari et al., 2007; Cong et al., 2010; Romero and Molina, 2011).
Creation	• Explore types of partnerships and business chains. • Define network and search for partners. • Select and recruit consortium members. • Enterprise profile definition. • Register, sign contracts, and provide tender. • Perform task decomposition. • Negotiate with customers and partners. • Contract awarding and management. • Estimate task price and budget allocation. • Quality goals formulation. • Establish ICT infrastructures and define access rights.	(Camarinha-Matos and Afsarmanesh, 1999; Mikhailov, 2002; Feng et al., 2007; Sari et al., 2007; Cong et al., 2010; Romero and Molina, 2011).
Operation	• Request for quote from partners. • Distribute production tasks to partners. • Monitoring the progress of the project. • Resolving possible conflicts between the members. • General management of all activities. • Perform task scheduling and tasks assignments. • Establishment business processes. • Set-up infrastructures and governance model. • Detailed planning for contract. • Operational feedback and adjustment. • Pay attention to environmental regulations (trades, laws, taxes, fines).	(Camarinha-Matos and Afsarmanesh, 1999; Mikhailov, 2002; Carvalho et al., 2005; Sari et al., 2007; Cong et al., 2010; Romero and Molina, 2011; Sadigh et al., 2017).
Continuation/ re-continuation	• Evaluate partners performance. • Re-schedule partners and their activities in case of unexpected events or disruptions. • Operation adjustment. • Infrastructure configuration.	(Camarinha-Matos et al. 2000; Feng et al., 2007; Sari et al., 2007).
Evolution	• Adapt business strategies to respond to new trends. • Prepare progress submission schedule. • Submit progress report. • Quality adjustment and evaluation.	(Carvalho et al., 2005; Sari et al., 2007; Romero and Molina, 2011).
Dissolution	• Plans dissolution. • Performance evaluation. • Benefits distribution. • Assets liquidation. • Deploy technology and knowledge transfers' initiative. • Provide after-sales services to the customer/market.	(Carvalho et al., 2005; Feng et al., 2007; Cong et al., 2010; Romero and Molina, 2011).

5. Implications, Conclusion, and Future Direction

5.1.Implications of Study

The increasing significance of "digital transformation" also referred to as digitalization facilitated by advanced ICT in VEs is receiving increasing attention. As such VEs, which are temporary alliances of organizations, are also changing their business model and strategies to take advantages of market opportunities. In a VE, each partner organization provides its own core competencies and resources in areas such as production, marketing, manufacturing, etc. to achieve the needs of the customer's, after which the VE consortium is decommissioned (Sari et al., 2007). Traditional ways of enterprises collaborating in stable supply chains network will no longer be sufficient in today's digitalized economy (Sari et al., 2007). Respectively, due to the COVID-19 pandemic businesses are increasingly faced with responding to the advent of digitalization that disrupt market boundaries. In order to address these changes, businesses collaborate digitally as VEs to discover new opportunities to share resources, competences and knowledge to gain competitive advantage by building on which strategies they should adopt, specific resources, and how enterprise's internal organization structure should change to support changes during the COVID-19 pandemic (Verhoef et al., 2019).

Findings from the literature, mainly examined the impact of ICT on enterprises and applications of ICT in businesses (Javed and Yasir, 2019; Jnr, 2020). To the best of our knowledge, there has been no review studies that explores digitalization of VEs during the COVID-19 pandemic, which investigates how organizations employs digital technologies to develop innovative digital business model that helps to create more value for VEs during crises (Verhoef et al., 2019; Jnr et al., 2020). Similarly, there are fewer studies that aims to fully support the life cycle operations of VE models in a digital manner. Therefore, this study contributes to the body of knowledge by promoting the digitalization of VEs as an approach to underpin and guarantee the successful operation of VE life cycles amidst the pandemic. This study focused on the inhibitors of VEs and presents the general functional requirements for a VE life cycle that can be used for designing and managing business operations digitally in improving the collaborative business processes within the life cycle of VEs. It can be systematically adopted by business practitioners who wants to design and deploy VEs. Additionally, findings from this study can be useful for business managers in developing best practices to support enterprises in implementing inventive approaches that promotes digitalization of business process during and after the COVID-19 pandemic.

5.2.Conclusion and Future Direction

The impacts of the COVID-19 pandemic on organizations have significantly changed rendering many business models obsolete (Zangiacomi et al., 2020). Hence, digitalization has become increasingly vital for VEs seeking to survive and achieve competitive advantages amidst the COVID-19 pandemic (Jnr, 2020). However, to date, fewer studies have explored the digitalization of a VE's life cycle. Also, the critical factors that inhibits the successful digitalization of VEs amidst and beyond the COVID-19 pandemic are still largely unexplored. To address these gaps, this current study contributes by offering a complete discussion on the

theoretical and practical underpinning concept of digitalization of VEs, general functional requirements for the various phases of digitalization of VE's life cycle as well as the key factors that may inhibit digitalization of VEs amidst the COVID-19 pandemic. Respectively, this paper extends the body of knowledge in VE studies by presenting 5 new findings. First, the review reveal that conceptual approach is the most employed method by prior studies in investigating digitalization of VEs, followed by literature review, and then case study and interview. Secondly, findings reveal that digitalization of VE studies were carried out mainly in Portugal and Brazil as compared to other countries.

Third, most of the studies reviewed were recurrently conducted towards examining the life cycle of VE, followed by general background of a VE, and factors that influence digitalization of VEs. Fourth, this review also presents 21 prior studies that examined digitalization of VEs and further identify the VE life cycle. The fifth findings from this review presents the factors that influence digitalization of VEs amidst and beyond the COVID-19 pandemic. Regardless of the aforementioned contributions, this study has several limitations. First, the keywords that was used to carry out the search may limit the concepts that were identified from the literature. Secondly, this study mainly used secondary data, no primary data was employed to verify the factors that influence digitalization of VEs. Also, no theoretical model was proposed with hypotheses for further validation. Future studies will include more search keyword to extend retrieved data from the literature. Additionally, the authors will develop a research model based on the life cycles and factors derived from the literature and primary data can be collected using surveys from enterprises to statistically validate the model after the COVID-19 pandemic.

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