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Autonomous VOs management based on industry 4.0: a systematic literature review

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Abstract

The virtual organization (VO) emerged intending to improve products and services in a globalized environment through collaborative work between organizations of different kinds. There is abundant literature around this topic for more than ten years. Today, with the mandatory trend of digital transformation, the aim is to redefine VO concepts and study them in the context of Industry 4.0. This paper will study the evolution of VO, from its beginnings (2010) to 2020, with a systematic literature review (SLR). This SLR will be quantified by a meta-analysis, which will allow an orderly view of the findings found. The objective is to find all the studies that have been carried out on VO frameworks based on Industry 4.0, collaborative works, and autonomous processes.

Keywords Virtual Organization · Industry 4.0 · Inter-organizational collaboration · Digital organizational transformation

Introduction

The VO was born with the aim of supporting SMEs to face the demand for products or services that they could not face on their own (Antonelli et al., 2015; Estanyol and Lurgi, 2011; Hao et al., 2014). Today, competition is global, and technology is the main supporting factor for these news organizations' operations to work transparently and smoothly (Polyantchikov et al., 2017). Digital transformation is part of this change that all kinds of organizations face (Lazarova-Molnar et al., 2018). In this context, customer demands have changed (Osorio et al., 2011; Wamamu Kanyi, 2017), asking for customized requirements (Chen et al., 2011; Narendra et al., 2016). For that, organizations will have to respond quickly, with the support of collaborative work (Oppenheim et al., 2011).

To meet these needs, it is intended in a first instance, to define the concepts about VOs, their standards and identify the works related to this subject through a SLR, and the results will be shown through a meta-analysis with their respective analysis and discussion.

This SLR aims to provide a clearer understanding of the different proposals for VO management, collaborative inter-organizational processes, and analytics or Datamining tasks in VO administration through a selective reference of the literature. Around these topics, some authors have ample time in the study of VO, from VO formation (Afsarmanesh et al., 2011; Boukadi et al., 2010) to optimal partner selection algorithms (Chen et al., 2011; Msanjila Afsarmanesh, 2010). Also, there are works for optimal knowledge management to efficiently gather different organizations' contributions to achieve a common good (Al-Busaidi and Olfman, 2017; Stochitoiu et al., 2018; Wang et al., 2010). On the other hand, in the subject of data analytics, works were found that contribute with tools, methodologies, and architectures to visualize the results of VOs (Bohlouli et al., 2014; Lazarova-Molnar et al., 2018; Wang et al., 2010).

The lack of autonomous mechanisms of integrating independent organizations to form VOs capable of self-managing has been identified in the revision. No case studies of autonomous VOs have been found. Also, there is a lack of formalization and collaborative models for VOs in the Industry 4.0 context. The indirect causes of this could be because organizations do not have enough technological resources, experience, or know-how in these specific issues (Ferreira

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et al., 2012). The effects of these shortcomings are reflected in the lack of competitiveness in a globalized scenario, a tendency to disappear from some organizations due to obsolescence, or a lack of resources for a digital transformation (Antonelli et al., 2015).

This research work carries out an SLR about these topics based on the meta-analysis of different results found in the literature. It is organized as follows. Section 2 provides the related works that contain literature reviews about VO frameworks. A comparison is made between them and this study. Section 3 provides background about VOs, particularly in the context of Industry 4.0. Section 4 explains the methodology of SLR used, and a preliminary analysis of the selected papers is presented in Sect. 5. Section 6 presents an in-depth analysis of selected papers, categorized by the SLR research questions, which be quantified in a meta-analysis of VOs frameworks based on Industry 4.0, collaborative environments, autonomous processes, and VOs sustainability issues. Section 7 discusses the gaps, challenges, and future works for each research question.

Related works

In previous years, SLRs have been carried out about VOs with different approaches. In the most recent work, in 2019, Semar-Bitah Boukhalfa (2019) performed a state of the art to obtain information about organizations' association and cooperation processes. Based on their analysis results, they proposed a meta-model of collaborative inter-organizational processes through the collection of knowledge. In 2016, Priego-roche et al. (2016) carried out an SLR to collect previous works dealing with engineering requirements for a VO. Based on the reviewed papers, they propose a partial business process design using business process modeling notation, and finally, a framework for VO requirements. The contribution of this work is that the authors propose a framework, which covers internal and external organizational aspects and, on the other hand, analyzes the VOs cross-sectionally at the intentional, organizational, and operational levels. However, in this work, only the intentional level is detailed, and the business process models and information systems of the organizational and operational levels remaining to be specified. In 2014, a group of researchers carried out a literature review to describe a taxonomy that allows the classification of VOs (Putnik Cruz-Cunha, 2014). The benefit of this contribution is that it allows appropriately related terms to be grouped and categorized based on VO characteristics defined since the mid-1990s in the literature. Finally, in 2014, Hao et al. (2014) carried out an SLR to identify requirements to develop a tool that supports the entire life cycle of a virtual factory (VF), from the creation to its dissolution. Once the SLR is carried out, they identify the proposals' gaps and weaknesses and provide tools to define the VF business model and the VF business processes and management practices for each process. This proposal is focused on providing SMEs with a methodology and a technological platform to form a VF to manufacture complex products and maintain communication between companies in real-time.

Table 1 compares the main contributions of the SLRs related to this study. Each SLR has a particular objective, such as the work of Semar-Bitah Boukhalfa (2019) whose objective is to design a meta-model of a VO, or Priego-roche et al. (2016) proposes a framework to define the conformation requirements of a VO. In (Putnik Cruz-Cunha, 2014), a classification of all the terms involved in a VO is carried out, and finally, in (Hao et al., 2014), the SLR is carried out to design a methodology and a technological platform that supports the entire life cycle of a VF in a collaborative environment. This SLR proposes a meta-analysis for the current context, where Industry 4.0 technologies and autonomous computing paradigm (Aguilar et al., 2018a) are a transversal axis of the proposal. Particularly, the contributions of this research work are listed below:

- Identify the strengths and weaknesses of previous proposals from the point of view of the Industry 4.0 context, collaborative processes, and autonomy.
- Identify the phases of the life cycle of a VO since of the Industry 4.0 paradigm.
- Analyze the collaborative inter-organizational models to identify new opportunities.

Table 1 SLR comparison

Author	Systematic literature review contents					
	Meta-model	Framework	Taxonomy	Life cycle	Autonomy	Industry 4.0
[1]	X					
[2]	X	X		X		
[3]			X			
[4]				X		
OUR SLR	X			X	X	X

[1] Semar-Bitah Boukhalfa (2019), [2] Priego-roche et al. (2016), [3] Putnik Cruz-Cunha (2014), [4] Hao et al. (2014)

Table 2 VO Definition

Author	VO definition
[1]	"VO is an association of (legally) independent organizations (VO partners) that come together and share resources and skills to achieve common goals, such as acquiring and responding to a market/society opportunity".
[2]	Virtual enterprise means a temporary organization for enterprise achieving desired goals, sharing cost and technology, sharing risks and interests
[3]	A Virtual enterprise is a temporary alliance that produces a service or product corresponding to a business opportunity. Most business components of a VE are derived from member enterprises (MEs) and are Distributed across the value chain between MEs

[1] Boukadi et al. (2010), [2] Cong et al. (2010), [3] Kim et al. (2013)

- Study the different types of analytical tasks that have been applied in these proposals.
- Propose preliminary ideas for a collaboration meta-model of VO based on Industry 4.0 and autonomous computing paradigms.

VO in the industry 4.0 and standards

Initial definitions around VO

There are different definitions of VOs in the literature (see Table 2), with similarities that can be identified among them. It can be summarized that VO is an alliance that is formed temporarily, in which they do not share only resources but also costs, interests, and goals to be achieved. The decision to be part of a VO has allowed increasing the business spectrum of small organizations without investing large amounts of money and resources. These organizations are interested in continuing with some services and products but cannot invest enough, for which the collaboration, association through agreements, roles, and clear benefits for the partners is carried out (Camarinha-Matos et al., 2017). Despite the benefits that this association brings, one of the most significant challenges they face is finding the ideal partners capable of achieving the objectives with a minimum margin of risk (Polyantchikov et al., 2017). In general, standards, frameworks, among others, are key for the VO, and are been defining to enable the development of VO. Some of them are the OAG (Open Applications Group) that is an inter-operation guideline for information exchange for enterprise applications; or open Internet standards like the well-accepted OMG (Object Management Group) CORBA-IIOP protocol for the distributed object-oriented platforms; or FIPA (Foundation for Intelligent Physical Agents) and OMG-Masif for the specification of intelligent and mobile agents; or XML-based emerging standards for electronic commerce like BizTalk, a vocabulary for defining common business processes in e-commerce. (see Filos Ouzounis (2003) for more details). In the article (Camarinha-Matos et al., 2017), the authors describe the characteristics of Industry 4.0 related to collaborative networks, which have been summarized in Table 3, where they point that Industry 4.0 has been the enabling factor for the formation of VO since it allows growing digitization and interconnection of manufacturing systems, products, value chains and business models (Camarinha-Matos et al., 2017). The main characteristic that they consider from Industry 4.0 is the integration for an acceleration of the production process from an integrated value chain.

Regarding standardization of the life cycle of creating a VO, several authors have made contributions to guarantee its operation and sustainability to operate and manage virtual organizations. It is necessary to follow a series of standards, which have been studied for several years by different authors and have evolved and described in 1. It is worth mentioning that all the proposals and investigations of these virtual organizations operate through the support of Industry 4.0 technologies. The most recent works describe what the life cycle of a VO in the Cloud should be (Priego-roche et al., 2016; Zamanian et al., 2014), as shown in Fig. 1. The model is classified into three phases: the first phase is created and managed by the Virtual Breeding Environment (VBE). Phase 2 moves the VBE to the Cloud, and finally, in phase 3, the VBE creates the VO. This phase is divided into several steps. The first one defines the "Opportunity for collaboration," which identifies the characteristics that fit within the collaboration models: Collaborative business process, Collaborative project, and the problem to solve. In the next step, the "VO approximate planning" is designed, the VO business structure is defined, and the competencies, services, and components are identified. Once this structure is carried out, the "Search and selection of partners" meets the specifications. This step is iterative because new partners may be required during the process, or some may be changed due to a failure. A "Negotiation" is carried out with the selected partners to reach agreements between the different actors. A "Detailed planning of VO" is carried out with this information, assigning roles according to established needs and selected collaborative models. Finally, it is carried out the "Contracting" step between the selected partners, organizations, and Clouds, establishing the service-level agreement (SLA), with the characteristics and quality of the service, and its cost, among other things. Finally, the "VO Configuration" is carried out, which grants permissions in the Cloud to start operating.

Guamushig et al. (2019) perform a characterization of the fourth generation of VO within the context of Industry 4.0, where five main characteristics were identified, summarized

Table 3 Characteristics of industry 4.0 in collaborative networks (Camarinha-Matos et al., 2017)

Characteristic	Approach
1 Vertical integration	"Integrating processes vertically throughout the organization, through networks of intelligent production systems."
2 Horizontal integration	"Creation of networks throughout the value chain to achieve cooperation between organizations"
3 Whole processes in the value chain	"It involves all engineering activities to fulfill the complete life cycle of the product."
4 Acceleration of manufacturing	"Transform processes into flexible, accelerate and optimize the entire value chain using exponential growth technologies."
5 Digitalization of products and services	"Convert each stage of the value chain into an intelligent process, applying sensors, better computing capacity, data management and communication to products.
6 New business models and customer access	"Take advantage of the data generated by the collaborative environment in the digitalization era to strengthen each stage of the life cycle of the value chain."

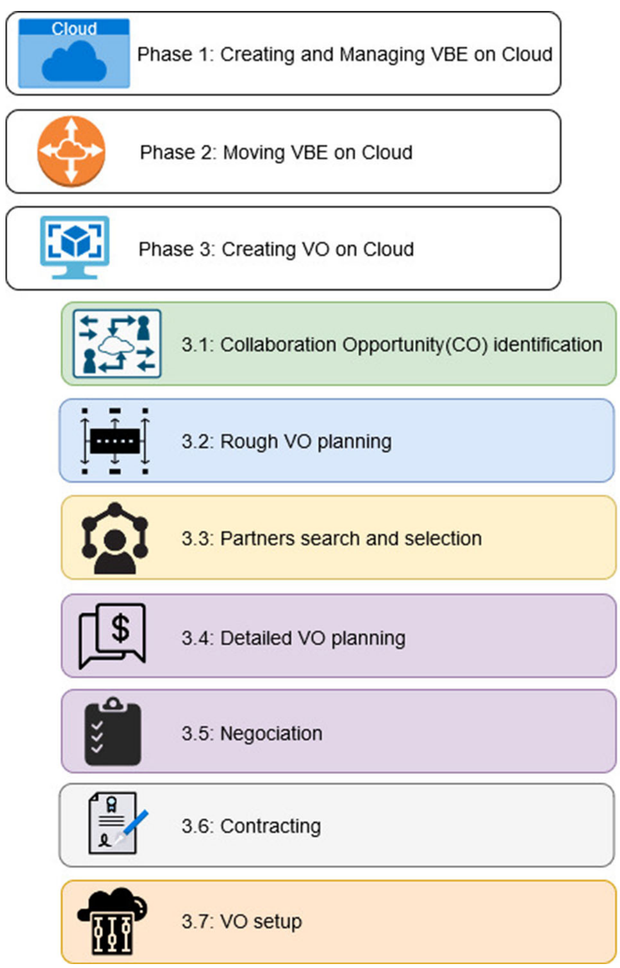

Fig. 1 VO life cycle (Zamanian et al., 2014)

in Table 4). These characteristics consider aspects like the infrastructure of the VOs, the elements to share between them, among other things.

The research and development route of the virtual organization

Figure 2 shows a chronological and thematic perspective of the principal authors linked to our subject. The author Afsarmanesh et al. (2011) (2003–2018) and her team have worked for fifteen years in VOs. Her outstanding efforts are focused on obtaining a basic knowledge of the business, such as the objectives, strategies, and challenges that organizations face when collaborating between small and large companies. In this sense, they have carried out a characterization work on suitable environments to form VOs, collaborative network models and have proposed formal models for creating virtual organizations. Camarinha-Matos et al. (2017) (2009–2019) has worked on collaborative networks, business ecosystems, and VO generation environments, highlighting the importance of inter-organizational collaboration to improve productivity and stay competitive . The authors Romero Molina (2010) (2009–2019) explain organizations' behavior that collaborates applying advanced technologies, and how productivity and quality of service improve when partnering strategically, forming VOs. These authors propose new models of processes for a VO in order to obtain all partners' benefits. Aguilar et al. (2018a) (2015–2020) presents a specification of autonomous cycles based on data analytics techniques that automate tasks that require processing data from different sources to obtain knowledge used for decision-making in any field. This author has applied this concept of autonomous cycles in learning, in communication systems

Table 4 Characterization of a VO 4.0 based on industry 4.0 (Guamushig et al., 2019)

No	Characteristics	Description
1	Allies	This characteristic refers to the participating organizations (PO) involved in forming the VO, which must meet different essential characteristics for their effective participation.
2	Elements	to share They are those OP resources that become part of the VO to collaborate and achieve common goals.
3	Infrastructure	VO4.0 works in the cloud by using a cyber-physical system shaped by the different technologies that support it. Theoretically, it does not have a physical location for its exclusive management.
4	Time	Refers to temporality, being VO4.0 dynamic, it is subject to having a beginning and an end depending on the need to conform it.
5	Offer	It results from the formation of the VO4.0, either products or services, which determines the lifetime of the VO conformation.

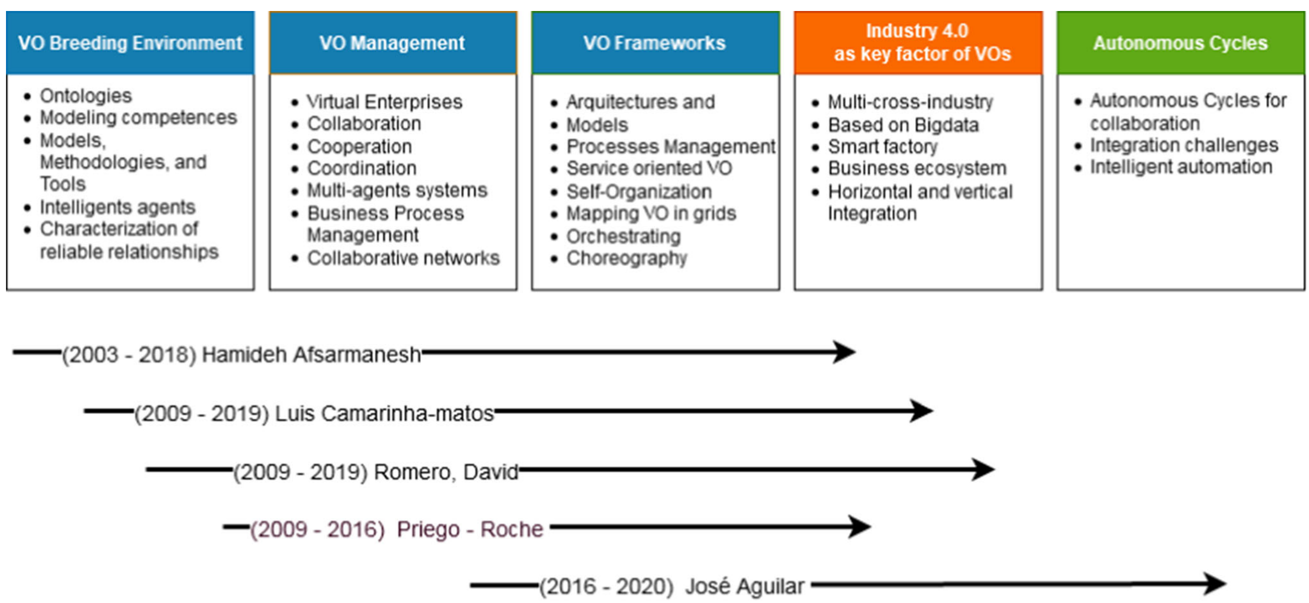

Fig. 2 The research and development route of the virtual organizations

(Aguilar et al., 2018c), in nanotechnology and the industry 4.0 (Sanchez et al., 2020a), among other domains. This concept is interesting because allow the integration of VOs using autonomous cycles. Priego-roche et al. (2016) (2009–2016) focuses on characterizing VOs and explains all the elements of a VO based on studying the objectives, strategies, and business processes involved to obtain the best income results. In her most recent work proposes a comprehensive approach, called 360 degrees, based on a horizontal and vertical analysis of the VOs. Finally, the most recent research about VOs adds Industry 4.0 as a technological base of the new generation of VOs (Lopez et al., 2020).

In order to fulfill the objective of this study, the methodology proposed by Kitchenham (2012) to develop a SLR, and the PICOT search protocol defined by Miller (2001), have been applied. Based on this, the following subsections indicate the steps followed for the literature search. A first aspect to consider is the PICOT description, after the definition of the research questions, then the search strategy and inclusion/exclusion criteria are explained, followed by the search strings, and finally, the flow of the search process is detailed.

PICOT

According to the PICOT model, the *Population* established are: Organizations that need to integrate with others in an autonomous way to achieve specific goals, independent of the location and competencies of each one. The *Interven-*

Table 5 Research questions

Question	Research question
RQ1	Are there autonomous VO frameworks for digital transformation in the contexts of Industry 4.0?
RQ2	Are there collaborative models for the integration processes of independent organizations?
RQ3	Are there data analysis tasks for self-management of VOs?
RQ4	Is there a framework/model or architecture formed by industry 4.0 technologies and VOs' sustainability issues?

tion is: Autonomous VOs. The *Comparison:* Associations, consortia, outsourcing, joint venture. The *Outcome* is: a list of challenges to overcome, and finally, the *Context* is: The Industry 4.0.

Research questions

Delimiting the area of knowledge of interest related to the topic of autonomous VOs in the context of Industry 4.0, four research questions were established in Table 5: topics related to frameworks, models, or methodologies for the creation and management of VOs; on the other hand, collaborative models for an inter-organizational approach; works that have applied analytical tasks or data mining, for self-management of VOs or collaborative inter-organizational processes and finally, about VOs sustainability issues.

Search strategy

For collecting documents, a search in each of the selected databases was carried out: Scopus, IEEE explore, ACM Digital Library, Springer, Elsevier, and Proquest. The inclusion criteria determine the specific characteristics that the selected articles must-have. The intention is to select research in one of these databases, and concerning time, the articles published since 2010 because the Industry 4.0 concept begins to be introduced. On the other hand, German and Spanish works are considered, in addition to English, since it is in Germany that the Industry 4.0 paradigm was born. The exclusion criteria have been specified, which filter the documents that, despite having met the initial criteria, have additional characteristics that are not suitable for this research, such as gray literature, research on social issues, among others. The inclusion and exclusion criteria as filters for the selection of publications are listed in Table 6.

Finally, four quality criteria are established to evaluate the publications, which are listed in Table 7. These have been defined based on the research questions to refine further the search for relevant documents that accurately answer each question.

Table 6 Inclusion and exclusion criteria

Type	Criteria
Inclusion	*IC1*: Only works in the databases will be included *IC2:* Works that have been published since 2010 *IC3:* Works in German, Spanish and English
Exclusion	*EC1:* Gray literature *EC2:* Research on social issues, since the focus is computer technology. *EC3:* Non-digital and without full access publications

Table 7 Quality criteria

Question	Quality criteria
RQ1	Does the study propose a framework, meta-model, protocol, architecture, or detailed language in the formation of VOs for a digital transformation or under the context of Industry 4.0?
RQ2	Does the study propose a collaborative or an integration model for the formation of VOs?
RQ3	Does the study describe data analysis or analysis techniques to manage VOs? Does the study describe data mining techniques, processes, and other mining techniques for managing VOs?
RQ4	Does the study describe the impact of industry 4.0 on VOs' sustainability?

Search strings

The seven search strings correspond to each research question. They were built based on the search terms listed in Table 8, using the logical operators "OR" and "AND" . The terms described in Table 8 have been classified into eight categories to facilitate the search strings definition. Table 9 shows the search strings used in this work.

Search process flow

To support the management of publications and the literature review process illustrated in Fig. 3, the StArt tool that supports Systematic Review was used (Fernández-Sáez et al., 2010) to define all stages in the selection procedure.

In the first stage, 1.957 duplicates papers were removed from 8.840 initial papers found, and inclusion and exclusion criteria described in Table 6 were applied to publication's titles, leaving 265 articles. In the second stage, the abstracts were examined to identify relevant publications for each research question, applying the inclusion and exclusion criteria, where obtained 100 papers. In the third stage, the analysis of the selected publications' contents was carried out applying the quality criteria described in Table 7, extracting 60 papers. Finally, after studied all papers, were selected 32

Table 8 Search terms

Topic	Cod.	Search term
Collaboration/Integration	A1	Collaborative framework
	A2	Collaborative model
	A3	Organizational integration
	A4	Collaboration
VOs	B1	Virtual enterprise
	B2	VO/Virtual organisation
Autonomous processes	C1	Self-management
	C2	Autonomous
Digitalization/Industry 4.0	D1	Industry 4.0
	D2	Digital transformation
	D3	Digitalization
	D4	Industry IoT (IIoT)
Frameworks/Formal approach	E1	Framework
	E2	Formal approach
Datamining/Analytics	F1	Data mining/Processes mining/Mining
	G1	Data analytics
	G2	Data analysis
Organizations/Enterprises	H1	Organization/Organisation
	H2	Enterprise
Sustainability	S1	Sustainability

Table 9 Search strings

String	Boolean chains: Question 1
S1	((B1 OR B2) AND (D1 OR D2 OR D3) AND (E1 OR E2)) AND IC1 AND IC2 AND IC3
S2	((B1 OR B2) AND (E1 OR E2)) AND IC1 AND IC2 AND IC3
S3	((B1 OR B2) AND (D1 OR D2 OR D3)) AND IC1 AND IC2 AND IC3
	Boolean chains: Question 2
S4	((A1 OR A2 OR A3 OR A4) AND (B1 OR B2 OR H1 OR H2)) AND IC1 AND IC2 AND IC3
	Boolean chains: Question 3
S5	((G1 OR G2) AND (B1 OR B2)) AND IC1 AND IC2 AND IC3
S6	((F1 OR F2 OR F3) AND (B1 OR B2)) AND IC1 AND IC2 AND IC3
	Boolean chains: Question 4
S7	((B1 OR B2 OR H1 OR H2) AND (D1 OR D2 OR D3 OR D4) OR (E1 OR E2)) AND S1 AND IC1 AND IC2 AND IC3

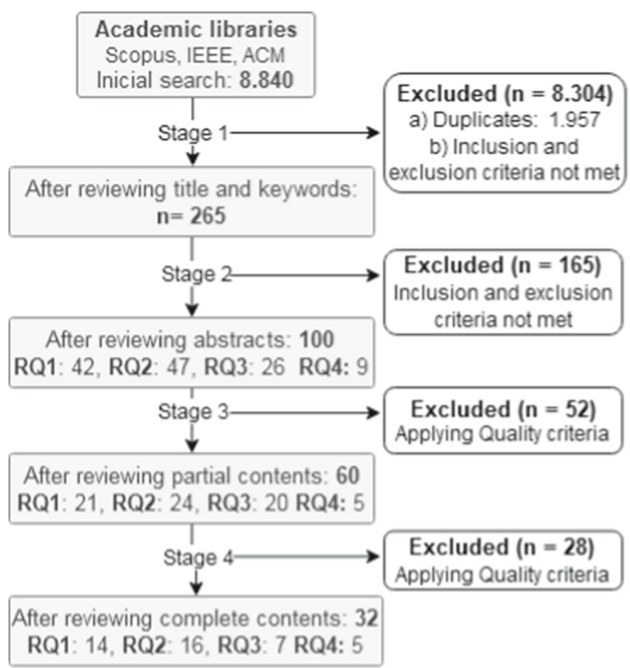

Fig. 3 Flowchart of the selection process

papers as the most relevant, according to the research questions to carry out the papers' analysis. Although 32 papers were selected for a more in-depth analysis, the 60 papers obtained in stage 3 were considered throughout for this SLR.

Preliminary results

In the preliminary results, an analysis was made by the country and by crucial questions. In Fig. 4, the studies correspond to countries, which industrially and techno-

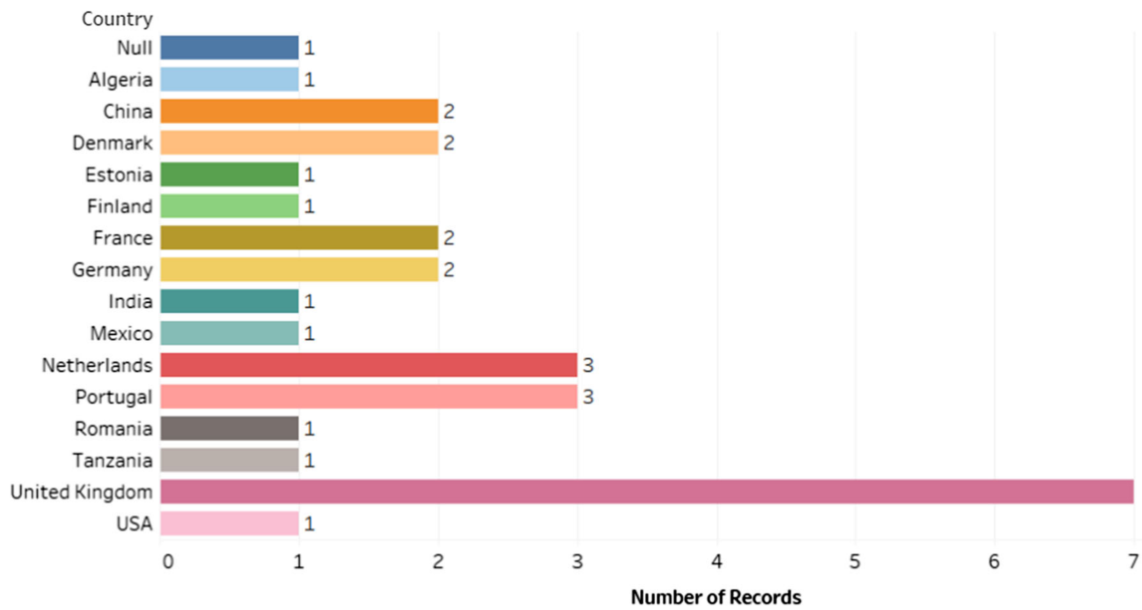

Fig. 4 Country vs Number of Publications

logically are among the most productive and competitive countries, according to the Organization for Economic Co-operation and Development (OECD), in the last ten years (OECD, 2010). These countries are United Kingdom, Portugal, Netherlands, Germany, France, China, and Denmark. The research works keep the same number from 2010, but it has increased in the last year 2019. Asian countries, such as South Korea and Japan, have no publications, maybe because most of their publications are published locally in their native languages, which are not considered in this study.

The United Kingdom's significant contribution in this field is the tremendous financial support between 2000 and 2011 through the Interdisciplinary Collaborative Research in Advanced Knowledge Technologies (AKTIRC) and the Collaborative Advanced Technologies in the Grid (CoAKTinG) programs. This project aimed to support knowledge management and distributed scientific collaboration (Choudhary et al., 2011). On the other hand, in the same years, the "European Collaborative networked Organizations LEADership initiative (ECOLEAD)" emerged, a project that integrated 20 allies from 14 European countries, such as Denmark and Netherland, France, Germany, and Portugal. As a result of this alliance's collaborative work, it gave the creation of VO tools and all the methodological support for creating VO and the development of the different phases of the VO life cycle (Paszkiewicz Picard, 2009).

Figure 6 shows the word cloud based on the keywords of the selected documents. The words collaboration and groupware stand out because all VO is carried out in a collaborative environment, and most of the proposals provide solutions to facilitate communication collaboration between

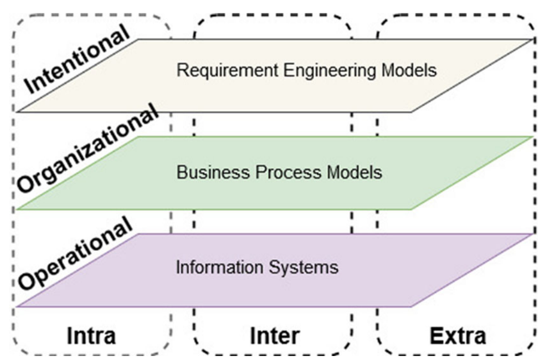

Fig. 5 VO Framework by Priego-roche et al. (2016)

partners. Also, there are the words that can be considered synonymous: VOs, virtual companies, and virtual corporations. There are also keywords related to technology topics, such as the Internet, technological-innovation, cloud computing, business-data-processing, and knowledge management, which correspond to the Industry 4.0 paradigm. Finally, there are words related to organizations in general, such as organizational-aspects, organizations, and companies.

Analysis of reviewed papers

Autonomous VO frameworks for digital transformation based on industry 4.0

Regarding autonomous VO frameworks, as is shown in Table 10. and Fig. 4, there are significant researches from 2010 to 2019. The authors Afsarmanesh et al. (2011)

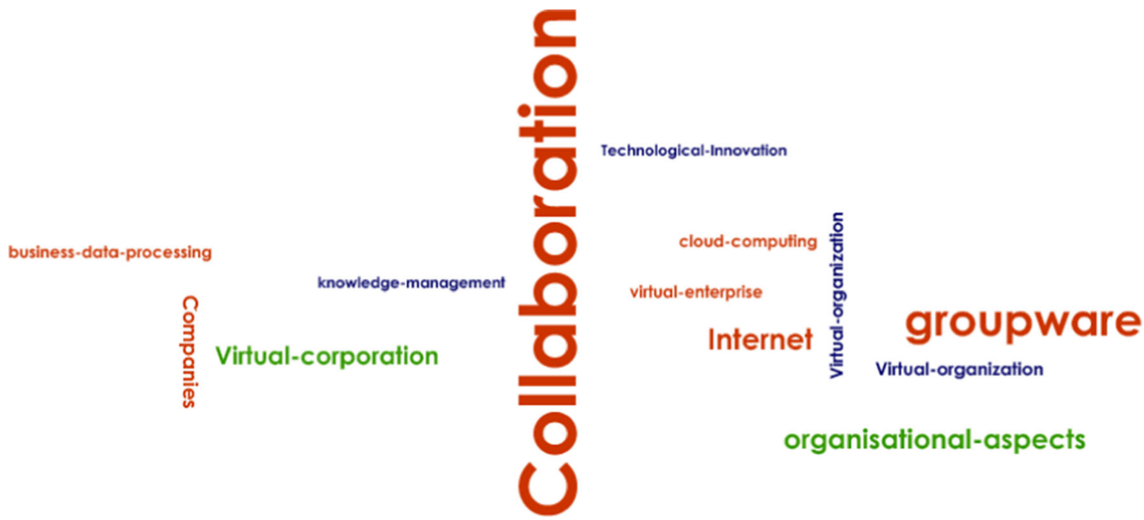

Fig. 6 Keywords word cloud

Table 10 Topics related to VO frameworks

Topic	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Methodologies	X	X		X	X	X			X		X		X	X
Service-Oriented	X	X	X					X			X		X	
Architectures							X	X	X					
Integration tasks	X								X	X				
Industry 4.0												X	X	

[1] Msanjila Afsarmanesh (2010), [2] Romero Molina (2010), [3] Osorio et al. (2011), [4] Afsarmanesh et al. (2011), [5] Ferreira et al. (2012), [6] Priego-Roche et al. (2012), [7] Shadi et al. (2013), [8] Li Wei (2014), [9] Priego-roche et al. (2016), [10] Ferreira et al. (2016), [11] Knoke et al. (2017), [12] Stochitoiu et al. (2018), [13] Cisneros-Cabrera et al. (2018), [14] Semar-Bitah Boukhalfa (2019)

and Camarinha-Matos et al. (2017), from Portugal and the Netherlands, respectively, have contributed significantly to this topic, in which they have proposed service integration platforms for collaborative networks to establish relationships in VOs. In China, the proposal "Everything-as-a-Service" (EaaS) platform for virtual companies on demand (Li Wei, 2014) fulfills the next requirements of VOs: agility, reusability, and collaboration based on trust. The EaaS concept allows sharing the resources of allies in a network where the web services supported by XML are the critical components for the formation of VOs. The proposal bases its platform on the concepts of resource as a service (RaaS), process utility as a service (PUaaS), and data as a service (DaaS). With this, flexible integration of resources improves productivity in a collaborative environment, sharing intellectual property and giving quick responses to customer demands. The platform requires a VO administrator in charge of receiving orders and negotiating with allies.

Romero Molina (2010) base their proposal on environments for the generation of VOs, and their most relevant contribution is a VO Management Framework. This study compiles the author's previous works to create a tool covering the entire life cycle of a VBE, a controlled environment to foster an environment of trust and establish prerequisites for effective collaboration. This proposal includes a VBE reference model, a VBE management framework that includes a series of activities to be followed in the management of VOs divided into three perspectives: VBE stakeholder management, VO creation, and general management of VBE. It is complemented with a methodology for the instantiation of VBE using all the mentioned tools. This proposal has been applied in Brazil in a pilot plan to transform a classic model of industry clusters into a VBE model. The same authors, in (Romero Molina, 2011), propose after a framework of reference called "Green Virtual Enterprise (GVE)", which offers an approach to conceiving sustainable networks with fully flexible supply lines, based on five building blocks: objectives, key players, operating principles, life cycle and supporting technologies, creating and manage GVE and VBE reference models, and collaborative networked organizations (CNO).

Ferreira et al. (2012) propose a framework and a process flow to measure partner's performance in collaborative business environments, detailed in section VI.B. Priego-

Roche et al. (2012) carry out a business process design at the VO's intentional level. The same authors, in (Priego-roche et al., 2016) propose a model-based framework to obtain the VO requirements by analyzing perspectives such as intra-organization, inter-organization, and extra-organization. They also analyze cross-sectionally the intentional, organizational, and operational levels, as shown in Fig. 5. Ferreira et al. (2016) studied Industry 4.0 as an enabler for effective manufacturing virtual enterprises. They attribute the lack of impact of technology in the industry to the lack of vertical and horizontal integration, both commercially and technically. They argue that through Industry 4.0, better interoperability will be achieved by creating cyber-physical production systems that allow a company to have flexible, efficient, and correctly virtual processes.

In 2017, Knoke et al. (2017) designed a reference framework and a methodology for collaborative business innovation for virtual enterprises. For experimentation, they developed a software platform for different industrial environments. In the same year, Stochitoiu et al. (2018) studied the relationship between knowledge and virtual companies' management. They claimed that without knowledge, management, and the application of Industry 4.0 would be difficult to carry out a virtual enterprise. Their main contributions are analyzing how knowledge management can improve competence, in which areas to apply, and what type of competencies will be required for the future in a virtual enterprise. In 2018, Cisneros-Cabrera et al. (2018), published a proposal for forming groups of partners that minimize the risk of the supplier and maximize the integration potential through a selection of the best partners to intervene in a collaborative process using the technologies of Industry 4.0. They facilitate the interoperability with business-to-business (B2B) platforms focused on the automotive and aviation industries. Finally, following the inter-organizational collaboration approach, Semar-Bitah Boukhalfa (2019) in 2019 designed a meta-model and a framework to cover autonomy, privacy, and heterogeneity and reduce the complexity of the global collaboration processes. This is part of the CIO-WF project, which aims to develop an inter-institutional collaboration platform using the cloud platform itself. The authors proposed a UML process model with the information of partners and objectives like a collaborative Business Process Model and Notation (BPMN) processes.

In Table 10, the previous works have been classified according to the aspect studied. It can be seen that more than 50% of studies have proposed methodologies for the creation of VO. The 35% have designing platforms and solutions as services. Another 30% have designed architectures to cover part or all the life cycle of a VO. The other 30% have proposed algorithms and integration mechanisms. Finally, the 20% have studied the Industry 4.0 paradigm as a transversal axis of the life cycle for the management of VOs.

It is important to note that in the search that was carried out using the keyword "IIoT Technologies", no research papers related to VOs were found. Scientific works on this topic have been particularly linked to analyze deployment platforms and communication mechanisms in the context of Industry 4.0. In this context, researchers are exploring these technologies to develop systems capable of connecting devices, in order to virtualize the companies and integrate them with others, which is essential for the future development of VOs (Ainsworth et al., 2021; Pivoto et al., 2021; Sasiain et al., 2020)

Collaborative models for integration processes of independent organizations

There are several relevant works in collaborative networks to promote virtual companies and organizations, as shown in Table 11. In (Wang et al., 2010), they did a collaboration analysis using mining work patterns based on collaborative user activities. They evaluate three criteria: one is the coincidence of the same word in multiple work items; the other is when the work item occurs; the third is the roles/activity of the user participating in the work item. This fact allows identifying and using the most important and relevant work elements during alliances.

In 2011, a similar proposal was presented in Choudhary et al. (2011), where they present a framework that allows learning from partners' data sources, generating the opportunity to reuse all knowledge discovered in the collaborative environment. Unified modeling language diagrams and an illustrative example are proposed for this framework. Based on the same concept of knowledge management, Palmer et al. (2013) have the proposal of a moderator who, through mining techniques, is capable of generating a semi-automatic methodology to generate rules by inserting discovered relationships.

On the other hand, Osorio et al. (2011) designed a service integration platform from independent organizations. This service-oriented proposal seeks to integrate each partner's information systems to improve the responsiveness of VOs by using the knowledge generated from the information obtained from autonomous computing agents that implement the services. In this way, patterns define the integration and distribution of the collaborative tasks. Another similar proposal is the Knowledge management of distributed companies using cloud-based big data analytics (Bohlouli et al., 2014). They design architecture and framework to integrate the knowledge that is generated in collaborative environments. The proposal is divided into four layers: presentation layer (PL), service layer (PaaS), physical layer (IaaS), and security layer (SL). With this framework, it is verified that it improves interoperability and productivity, being the platform capable of predicting failures by analyzing historical

Table 11 Topics related to collaborative models for VO

Topics	[1]	[2]	[3]	[14]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]
Based on data mining and Data Analytics	X	X	X			X			X	X	X		X	X		X
Analytics of Processes	X	X	X		X							X			X	
Ontologies							X									
Measuring performance				X				X		X						

[1] Wang et al. (2010), [2] Osorio et al. (2011), [3] Bohlouli et al. (2014), [4] Ferreira et al. (2012), [5] Norta (2015), [6] Lazarova-Molnar et al. (2019), [7] Mu et al. (2018), [8] Hao et al. (2014), [9] Palmer et al. (2013), [10] Choudhary et al. (2011), [11] Ferreira et al. (2016), [12] Knoke et al. (2017), [13] Choudhary et al. (2019), [14] Cisneros-Cabrera et al. (2018), [15] Mandal (2015), [16] Lazarova-Molnar et al. (2018)

data and improving the production process. On the other hand, Hao et al. (2014) propose a virtual business system factory platform for a collaborative business environment, enabling different factories to meet their business goals and provides a single point for all factories to access manufacturing and product information in real-time.

In 2012, a different proposal to previous ones is described in (Ferreira et al., 2012). They focus on identifying indicators to measure the performance of partners in a collaborative business network, such as critical success factors (KSF), key performance factors (KPF), and key performance indicators (KPI). The framework proposed is based on a life cycle of a collaborative business network, whose model starts from a business community, where business opportunities are accessed. The second phase is the VO formation, where evaluation, qualification, and selection of allies, and commitment signatures, are carried out. The third phase is the operation, where the product or service production is planned, managed, and monitored. Finally, the dissolution phase comes, where the profits are distributed, and an evaluation is carried out. This proposal includes a tool or software to improve information availability between partners and manage the business network members' performance indicators.

Emphasis has been placed on smart contracting for decentralized autonomous organizations in (Norta, 2015), whose study focuses on the life cycle of collaboration configuration between them. The life cycle configuration begins with designing a business network model with service types and partner roles. Candidate partners negotiate and exploit the model's relevant properties: loops, performance peaks, lifetime, utilization, start marks, and dead marks in the configuration life cycle. Another similar proposal is (Cisneros-Cabrera et al., 2018), which solves the hiring of allies who intend to collaborate in a VO. Microservices are proposed to facilitate the process by decomposing a call for tenders into a hierarchical tree structure of tasks and product components. The idea is to find intersections between tree nodes derived from the tender structure and a list of partners aligned to the requirements by performing matchmaking. About collaborative data analysis for industry 4.0, critical issues, challenges, opportunities, and models are addressed Mandal (2015). A significant contribution is (Mu et al., 2018), who carry out a selection of collaborative business services based on ontology to build automatically collaborative business processes. In Germany, several works focused on case studies involving infrastructure and recent technology, applied to the interaction and collaboration for the VOs Collaborative open innovation management in virtual manufacturing enterprises (Knoke et al., 2017), which was explained in the previous section. Also, in (Mandal, 2015) is proposed a model that allows collaboration in a supply chain, for which experiments were carried out in 122 companies. Furthermore, the study (Hao et al., 2014) focuses on the moderator's role to improve the concept of VO by integrating ICT solutions that allow dynamic network processes. This model involves message routing, data collection, and discovery, connection smart object integration, data transformation services, and finally, monitoring to ensure continuous model improvement.

In recent years, works have emerged that emphasize the application of data analytics in Industry 4.0 to improve collaborative processes. In these studies, they compile challenges, opportunities, and models in this area (Lazarova-Molnar et al., 2018; Sanchez et al., 2020b). In another similar work, Choudhary et al. (2019) promoted to apply knowledge management in collaborative environments to support SMEs that intend to form VO. They mention the importance of utilizing new technologies to achieve the required synergy at each stage of the life cycle of a VO, where it is proposed to use all the information generated and apply analytics and data, text, and process mining.

In summary, Table 11 presents the most relevant works on this topic, categorized in the base of the collaborative model used. A good number of works make their proposals supported by data analytics platforms. The 33% propose integration mechanisms. Another 20% of the works use ontologies to describe the life cycle of a VO, and 40% develop methodologies that cover the different stages in collaborative inter-organizational environments. Finally, only some works propose performance metrics.

Data analytics task to self-manage VOs

Regarding Data analytics tasks to self-manage VO (Perozo et al., 2013), it is found works related to data analytics applied to organizational issues, supply chains, and collaborative issues. It can see that authors from Germany, United States United Kingdom and Denmark have made contributions in this domain, by applying concepts of Industry 4.0, Big data analytics, Knowledge Management, and Data mining, to inter-organizational and collaboration fields. It is important to note that since 2017, the work related to the importance of data in VO construction has increased. Data mining, big data, and data analytics are vital tools to obtain knowledge that becomes valuable for VOs.

In the proposal of Lazarova-Molnar et al. (2019), a framework for Collaborative Data Analysis (CDA) for Industry 4.0 is designed. The research describes data collection processes to decision support in a series of concrete steps, such as: determining data analysis objectives and security expectations and defining security expectations from the data sensitive parts to share. These CDA objectives and safety expectations, once formulated, lead to the next process, that is, the requirements. This leads to define the required data flows and the concrete agreements between the collaborators, regarding the support for the decision that can be expected and provided. Notably, once the objectives are clarified and redefined to reflect the real situation in question, the next step is to define the security requirements and guarantees, where the agreements on privacy and security are obtained. Finally, the participants are approved in the CDA scheme and can start sharing data online or offline, protected following security agreements.

The articles (Palmer et al., 2013; Wang et al., 2010) talk about analyzing each stage of the life cycle of a collaborative process to discover patterns that benefit the management of a VO. They recommend using the information obtained to select partners, assign tasks, and evaluate results, which improve the management with feedback, to make better decisions autonomously. Similar work is proposed in Sanchez et al. (2020b), where the authors describe an autonomic cycle of data analytics tasks for self-coordination in manufacturing processes. This autonomic cycle is implemented and tested using an experimental tool developed to replay the production process event logs to allow the industrial process's auto-configuration.

Table 12 Data analytics tasks for knowledge management

Topics	Authors [1]	[2]	[3]	[4]	[5]	[6]	[7]
Clustering	X						
Identifying patterns			X		X	X	X
Classification and Recommenders	X	X		X	X	X	X
Text Mining				X			
Processes Mining	X	X		X		X	X

[1] Wang et al. (2010), [2] Lazarova-Molnar et al. (2019), [3] Bohlouli et al. (2014), [4] Lazarova-Molnar et al. (2018), [5] Palmer et al. (2013), [6] Choudhary et al. (2019), [7] Sanchez et al. (2020b)

Besides, other works focus on proposing collaborative platforms based on the partners' information and the different phases of the collaborative process of a VO (Choudhary et al., 2019). They manage the knowledge through analytical tasks, text mining, and process mining of VOs. There are proposals for solutions in the cloud, applying analytics of large amounts of data from partners (Bohlouli et al., 2014). In Lazarova-Molnar et al. (2018), Sanchez et al. (2020b), an analysis of challenges and opportunities is made when applying these techniques, emphasizing the use of Industry 4.0 technologies.

In Table 12, seven relevant works have been found that meet the third research question and are classified according to the data analysis tasks used. These studies' common objective is to apply mining tasks to manage the knowledge generated from the data produced by each stage of the life cycle of a VO. Some of the data mining tasks are clustering, classification, and, additionally, process mining, among others.

VOs sustainability issues under industry 4.0 paradigm

Currently, the sustainability issue in VOs has been approached from three different perspectives: protection of the environment, economic growth, and social progress (Camarinha-matos et al., 2013).

Peruzzini et al. (2013) propose a methodology to carry out a holistic evaluation of the sustainability of Product-Service Systems (PSS) in collaborative ecosystems. Firstly, they define a life cycle, and in each phase, they indicate the sustainability objectives (economic, ecological or social) to be achieved. Goals are set using KPIs measured using specific assessment techniques (i.e., Life Cycle Assessment LCA, Life Cycle Cost Assessment LCCA, SLCA Social Life Cycle Assessment) and normalized to obtain a value. Sustainability

Assessment (SA) unique allows the analysis and optimization of sustainability within the VO (Peruzzini et al., 2013). For Durugbo (2013), the partners of a VO are challenged to achieve the objectives that have been set, using the necessary resources in the planned time. Even though VOs are formed with the initial objective of having sustainable services, they usually have a large margin of uncertainty, making planning for future partnerships difficult. In this research, Durugbo (2013) identifies the reason for these uncertainties using an investigation model of the nature of the association uncertainty within operations and analyzes the guidelines to manage the associations' uncertainties during the provision of services sustainable through a qualitative analysis using 17 sources of secondary cases. Daudi Msanjila (2014) relate the VO's degree of sustainability with the trust generated for partners and clients. They affirm that if an organization has failed its sustainability, it is possible that it affects the reputation and generates some distrust in the partners. For this, they designed a TrustSEv system in order to improve the flow of information for the provision of services such as: Entering necessary information related to the VO, entering confidence values and confidence level, forecasting target goals for the next evaluation period, evaluate the sustainable trust value and trust level and finally define, authorize and assign rights to other users.

Polyantchikov et al. (2017) assert that partners' correct selection is the key to achieving sustainability in collaborative environments. For which the authors designed a methodology based on a set of criteria selected from other previous works. An evaluation was applied to a case study with several organizations that collaborate to achieve a common goal. Finally, a calculation tool is proposed for a faster member evaluation based on the criteria and score obtained.

Table 13 VOS sustainability proposals

Topics	Authors [1]	[2]	[3]	[4]	[5]
Methodology	X	X			
Sustainability evaluation		X		X	
Partner selection problem (PSP)			X		X
Conceptual model			X		

[1] Camarinha-matos et al. (2013), [2] Peruzzini et al. (2013), [3] Durugbo (2013), [4] Daudi Msanjila (2014), [5] Polyantchikov et al. (2017)

Discussion

Autonomous VO frameworks based on industry 4.0

The most relevant contributions have emerged in the years 2010 to 2012 (Ferreira et al., 2012; Msanjila Afsarmanesh, 2010); however, in these years the works are not related to the formation of VOs in the Industry 4.0 context. These works do not describe the technology or techniques to be used and most of them are theoretical works, and for the present time are obsolete due to the technological advancements in these last ten years (Romero Molina, 2010; Vizcarrondo et al., 2017). On the other hand, the studies that present platforms or software with case studies that support the theory, have the limitation of being out of context for the current time, with new technologies of Industry 4.0.

Also, there are contributions in collaborative issues for businesses that do not consider Industry 4.0 and current issues, such as obtaining knowledge of organizations from their shared data to generate autonomous processes (Choudhary et al., 2011). From the existing literature, there is a single work that talks about autonomy in VOs, but does not propose a complete solution. Similar phases in the life cycles applied in the described frameworks were identified, which can be synthesized in preparation of the VO, identification of the need or opportunity, process the requirements, select partners, specify the supply chain, sign contracts, product delivery and dissolution (Lazarova-Molnar et al., 2018; Priego-roche et al., 2016; Romero Molina, 2010). The enabling technologies mentioned in the reviewed works have been cloud computing, Big Data Analytics, mining of everything, vertical and horizontal integration, and the internet of things. However, no works were found that formalize the proposal according to the Reference Architectural Model for Industry 4.0 (RAMI 4.0), which is identified as a challenge for future works. It is necessary to study the life cycle of a VO with respect to the RAMI 4.0 standard. For this, concepts such as Multi-Agent Systems (Aguilar et al., 2005) and Reflective Middleware (Vizcarrondo et al., 2012) must be included, which will help in the modeling tasks of the processes in the VOs.

Collaborative models for integration processes of independent organizations

This is the topic that has the most contributions such as Priego-roche et al. (2016), Priego-Roche et al. (2009), in which are characterized the VO and defined a meta-model of VO. However, in these works is not defined the life cycle of a VO, only the intentional phase is analyzed. Some proposals of integration platforms exist, but only the design has been reached, without their application to case studies in the current context of the Industry 4.0 (Osorio et al., 2011; Sanchez et al., 2020b). On the other hand, there are have few jobs about autonomous VOs (Narendra et al., 2016) in which they do not specify the techniques or tools to be used. In this aspect, there is a gap in which it is possible to contribute with the application of autonomous cycles of data analysis tasks (Aguilar et al., 2018c; Sanchez et al., 2020b) to achieve autonomous VO (Lopez et al., 2019). In addition, various solutions were found for this problem, however, they need to be expanded adding technological management to achieve solutions that exploit current technologies. Additionally, it is recommended to apply data analytics tasks, like in Sanchez et al. (2020b). In general, it is necessary a well-defined and detailed proposal that specifies each phase of the life cycle in a collaborative environment.

Data analytics task to self-manage VOS

Concerning the knowledge management and data analytic as an enabling factor for VO, there are works since 2017 (Lazarova-Molnar et al., 2018, 2019; Leveling et al., 2014). However, the works are very general, without implementation and details about how to manage a VO in the context of the industry 4.0. In other contexts, important contributions have been found (Sanchez et al., 2020a, 2020b), where the value of data analytics has been exploited, and can be translated at all stages of the life cycle of a VO. They apply data mining to identify and select the best partners, to achieve the manufacturing of complex products. However, no studies have been found that apply data analytics to autonomously generate VO. Nor there are solutions for a monitoring stage, in which the process should be strengthened with feedback based on the knowledge generated. In this regard, there is an important gap to cover in which it is possible apply data analytics tasks using the MIDANO methodology (Pacheco et al., 2014) along with the autonomous cycles (Lopez et al., 2020; Sanchez et al., 2020a, 2020b), to form a self-adjusting iterative collaborative model. Another point to cover is to decipher the supply chain formation in a VO applying the aforementioned concepts, using the large amounts of data expected to be generated in a VO.

VOs sustainability issues under industry 4.0 paradigm

According to the different proposals, it can be seen that the different authors who have investigated the issue of sustainability in virtual organizations agree that the correct selection of partners affects the sustainability of VOs. For this reason, most of the proposals, methodologies, software, and metrics focus on the evaluation of partners and their results concerning the objectives initially set. On the other hand, several research works mention three pillars or perspectives that must be analyzed when evaluating sustainability. This approach depends on the objectives initially set, which may be environmental, economic, or social. It is important to note that no work evaluated presents concrete solutions related to Industry 4.0, where a gap has been found that must be worked in the future.

Challenges

The different methods that have been applied in the different reference works have been summarized in Table 14. 50% of the works make proposals for frameworks, methodologies, models and tools for the management and the formation of VOs. The authors focus on the creation of VO, selection of partners and propose tools for these purposes. Also, they have proposed methodologies to control the entire life cycle of a VO. However, these are works that could be improved if Industry 4.0 technologies are applied. Other authors have created smart agents and artifacts to monitor the partner trust process, in a controlled environment. But today, the processes are intended to be autonomous, so smart methods must be implemented before selecting partners to guarantee the performance of each one and reduce risk.

On the other hand, it is sought that the monitoring has the objective of identifying possible failures in the processes and intelligently preventing them. An interesting contribution is Ferreira et al. (2012), which based on performance indicators proposes a tool to determine the performance of each partner. However, the parameters must be entered manually, which could be improved by carrying out a predictive analytical work and data mining based on historic data of the organizations, to identify patterns linked to the performance metrics, and according to each pattern established the best configuration of partners.

The concept of everything as a service, proposed by Li Wei (2014), Sanchez et al. (2020b), is an interesting and valid topic that must be used in our context, where the challenge is to carry out cost-benefit analyzes for the partners. The meta-model proposed by Semar-Bitah Boukhalfa (2019) is a significant contribution, but must be updated to be applicable in the context of Industry 4.0. Finally, there is no much literature that responds to RQ3, related to analytical tasks and data mining for the formation of autonomous VOs, despite the fact that the works (Bohlouli et al., 2014; Choudhary et al., 2011, 2019; Sanchez et al., 2020b) study the importance of generating knowledge from the data provided by organizations for a purpose of common benefit, but no specific proposals have been found that demonstrate or implement these technologies (except the work (Sanchez et al., 2020b), but not for VO). At this point, a gap has been found, which requires being studied in the context of the life cycle of a VO, for which a meta-model is required that takes data into account as an essential factor, and their appropriate treatment in order to achieve autonomous processes, throughout the life cycle of a VO, from the identification of partners, distribution of attributions, definition of the collaborative model design and, virtual supply chain, until the product delivery.

Table 14 summarizes the challenges based on the three researcher questions: The biggest challenge involves applying Industry 4.0 as a transversal axis in the process of

Table 14 Classification of challenges

Topics	Challenges
Autonomous VOs Frameworks based on Industry 4.0	- Apply Industry 4.0 as transversal axis
	- Design a BPM in an autonomic way
	- Design autonomous cycles for performance measurement
Collaborative models for integration processes of independent organizations	- Develop a smart process for the selection of partners and distribution of responsibilities.
	- Optimizing the input of parameters applying predictive analytical processes and data extraction methods
	- Analyze benefit-cost and scalability to have continuous improvement processes based on the knowledge generated
Data analytics tasks to self-manage VOs	- Define a meta-modeling as a guide for the autonomous VO generation.
	- Specify data analysis tasks for each autonomous cycle throughout the life cycle of a VO
VOs' sustainability issues	- Improve sustainability evaluation parameters based on Industry 4.0.
	- Develop sustainability measurement methodology differentiating in three aspects: social, economic, and environmental according to the VO's priority and applying Industry 4.0 technologies.

generating autonomous VOs. For this, smart autonomous cycles capable of selecting suitable partners that guarantee performance, profitability, process optimization and risk reduction, must be implemented. In addition, the design of autonomous cycles is also required to measure performance and obtain feedback on the results. The design of these cycles must be designed and configured autonomously using Business Process Models (BPMs).

On the other hand, the input parameters in the current proposals are manually entered, which must be optimized by carrying out predictive analytical works and extracting them from the historical data of the organizations. Also, it is necessary to identify patterns linked to metrics of performance, in order to be used to analyze the best configuration and selection of partners, as well as the distribution of responsibilities and tasks. It is necessary to implement autonomous monitoring cycles that analyze the cost-benefit and scalability of the model, in order to obtain feedback iteratively to have continuous improvement processes based on the knowledge generated. On the other hand, it is necessary to design a metamodel based on the current context that serves as a guide for the formation of autonomous VOs. Finally, the specification and design of the data analysis tasks for each autonomous cycle throughout the life cycle of a VO, must be carried out for an autonomous management of VO.

Conclusion and future works

According to the SLR, there are significant contributions from the definition of methods for the creation of VOs to the description of methodologies for selecting partners. However, it has shown that these works were valid for a context very different from the fourth industrial revolution's current context. According to this gap found, it proposes future works, which use data analysis techniques to achieve smart autonomous cycles, capable of self-configuring and self-managing, and thus achieving flexible VOs (Sanchez et al., 2020a, 2020b).

Regarding the first research question, numerous works were found that propose frameworks and methodologies to solve different stages of the life cycle of a VO. In this sense, it has been identified that nothing specific has been proposed for autonomous VOs applying Industry 4.0. Regarding the second question about collaborative and integration models, theoretical proposals and some platforms satisfy these needs but are decontextualized. Finally, exciting studies and proposals about analytical tasks were found to generate intelligent collaborative environments for other contexts regarding question three. Thus, they do not respond to this study's primary object, which is VO's self-management.

Finally, to formalize an autonomous VO's complete life cycle in Industry 4.0, it is crucial to design and specify each autonomous cycle and its respective analytical tasks, following the architectural reference model of Industry 4.0 (RAMI 4.0), using concepts of context-aware (Aguilar et al., 2018b) to give more adaptability capabilities to these systems. It is also imperative to specify a Middleware, where each analytical task applied in each phase of the life cycle will be deployed, supported by the emerging technologies of Industry 4.0. In this way, there will be an ecosystem for the autonomous management of VOs. '

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