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A SYSTEMATIC LITERATURE REVIEW ON BLOCKCHAIN'S POTENTIAL FOR BOOSTING TEAMWORK IN BUSINESS PROCESS MANAGEMENT

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ABSTRACT

BlockChain Technology (BCT) has appeared with strength and promises an authentic revolution on business, management, and organizational strategies related to utilization of advanced software systems. In fact, BCT promotes a decentralized architecture to process management and the collaborative work between entities when these ones are working together in a business process. This paper aims to know what proposals exist to improve any stage of business process management using BCT because this technology could provide benefits in this management. For this purpose, this paper presents a systematic literature review in area of Collaborative Business Processes (CBP) in BCT domain to identify opportunities and gaps for further research. This paper concludes there is a rapid and growing interest of public bodies, scientific community and software industries to know opportunities that BCT offers to improve CBP management in a decentralized manner. However, although the topic is in early stages, there are very promising lines of research and relevant open issues, but there also is lack of scienti c rigor in validation process into the different studies.

I. INTRODUCTION

Over last decade, the use of process engineering principles on numerous environments is worldwide accepted as mechanism to increase the excellence, productivity and quality of any kind of organization [69], [70]. In fact, there are standards [1] and management guidelines [2], [3], [71], as well as important techniques and methods for ICT (Information Communications Technology) business environments [4], [5] that recommend to manage main business processes as mechanism for increasing efficiency and effectiveness within organizations associated with the utilization of advanced information systems [72].

In this context, BPM (Business Process Management) [6] is a well-known business strategy to achieve these goals what allows to obtain different advantages [7] (e.g., higher productivity, competitiveness, efficiency and reduced cost, among others). In addition, the business process definition is traditionally oriented to be executed centrally for a single company. In fact, there are many technologies (known as BPM Suites [8]) to manage, implement and execute these processes and, although this technology allows to assign specific tasks of the process to external actors, all those tasks

are orchestrated in a centralized way at process level.

This centralized architecture is appropriate for single companies, but it is not efficient when it is necessary to collaboratively involve multiple entities or companies into the same process. Some reasons for this situation are that each company usually has its interests and software systems, and they are usually reluctant to share business data of the process [9], [10], among others. In addition, each entity must also meet certain conditions or legal clauses with remaining entities participating when the process is executed by each entity. This aspect is very relevant in some Collaborative Business Processes (CBP) (e.g., supply chain or logistics processes, among others [9]).

Moreover, over the last decade, new technology has emerged that could provide a technological solution to exe cute and manage CBP. We refer to BlockChain Technology (BCT) [11]. This technology offers valued cost reductions by enabling transactions to be run in a peer-to-peer (P2P) way (i.e., as P2P processes) directly between entities or individual users. This execution can be carried out without requiring mutual trust between each party. The distributed blockchain was contextualized in 2008 by Satoshi Nakamato. The goal of this proposal was to establish a secure history to exchange data using a timestamp to verify each exchange. This architecture was designed to work without central authority. In fact, this solution was the technological base that caused the birth of crypto currencies such as Bitcoin [12].

These features have led to a rapid and growing attention on Blockchain since it was applied in the financial field with the development of crypto currencies. Since 2008, many applications of BCT have been and are been studied and researched in numerous real field and service [13] around the word (electronic health records [14], ownership management, financial market [15], energy supply [16], supply chain [17] and Internet of Things [18], among others) to build decentralized software applications whose architecture is based on shared agreements on decentralized data through a network of unknown participants [19].

Taking this context into account, it is possible to see the interest of public bodies and software industries to know the feasibility and opportunities that BCT offers to improve the process management (from the broad perspective of the word) in a decentralized manner. This collaborative management could become to offer better services to citizens and companies.

This study addresses the need to know the state-of-the-art of research papers offered by the literature where techniques, approaches or methods are proposed to improve collaborative BPM using blockchain technology. More precisely, this paper presents a systematic review and it deals with collaborative BPM and BCT when focusing on two parallel (but complementary) work lines: (i) supporting each activity of the BPM lifecycle with

blockchain approach, and (ii) executing collaborative processes using supporting tools based on BCT.

Therefore, main contribution of this paper is to provide complete knowledge and review of research papers that propose techniques, approaches or methods are proposed to improve collaborative BPM using BCT. In the scientific liter- ature, we found only a few review papers that target specific areas, instead of a complete overview of blockchain-related research within topic of collaborative BPM. In addition, our review covers the most updated papers in the aforementioned areas. In this sense, the systematic review has been carried out without filtering by publication date what allows to know all

research production that has been published on this subject. Similarly, this systematic review analyzes and discusses what activities (related to the BPM lifecycle) are supported by each primary study. This analysis has also allowed to: (1) identify the business contexts (healthcare, manufacturing, supply chains, etc.) where each primary study has been applied; (2) know specific applications in the industry about business process improvement using BCT; and (3) identify most popular used blockchain technologies in domain of collaborative business process management.

This analysis provides knowledge that is relevant, useful and valuable to decision-makers because it identifies trends and not-covered challenges that can be addressed by the research community. In fact, new research lines have been opened in our research group after considering the results of this systematic review. These research lines are related to software testing process and traceability process of biological samples within laboratories 4.0. Both research lines are mentioned as future works in conclusion section of this paper.

In short, this paper presents a comprehensive review of blockchain technology and its applications in domain of collaborative process management, which we perceive to be the strength of this paper.

Finally, it is important to mention that this systematic review has been carried out following the formal Kitchen- ham's methodology [24] to identify existing gaps and offer future guidelines of research on issues related to BPM in a collaborative context in BCT domain. This methodology is chosen because it has been successfully applied in many fields (e.g.. software engineering). In addition. Kitchenham's methodology has been extended with the snowball> technique [30] in order to improve the review protocol. This technique consists of analyzing reference and related works. among other aspects, of each primary study to be analyzed.

The rest of this paper is structured as follows. Related works are briefly presented in Section 2. This section also presents differences from our systematic review with all previous works that are identified in Section 2. Subsequently, Section 3 describes the planning of our systematic review process and, once search systematic protocol

has been executed, results are described in Section 4. Later, discussions on these results are offered in Section 5, and, Section 6 finally establishes future works and conclusions.

II. COMPARISON WITH RELATED WORKS

Although blockchain technology is related to financial ser- vices and the implementation of bitcoin cryptocurrency [20]. both the international research community and private corporations are trying to apply this technology in different areas. For example, blockchain is being very considered in recent years to improve the design of inter-organizational processes and their management. This growing interest has led to the publication in the scientific literature of several SLRs and reviews on this subject. Their main conclusions are briefly described below.

Konstantinidis et al. [21] have carried out SLR to identify business areas (applications and services) where blockchain technology has been used or is being applied in recent years. Authors also identify some of the possible challenges of this technology to improve its applicability in a greater number of business areas. Although authors identify challenges related to technological aspects (privacy, security, latency, and computational cost) of blockchain, it is not focused on the application of this technology in BPM domain what hinders to address and know BPM challenges that could be supported by BCT. These limitations are resolved in our paper, which identifies gaps and open issues of the state-of- the-art on research approaches that propose techniques, tools or methods to improve the collaborative process management using BCT.

Mendling et al. [19] study challenges of BCT in BPM context. Authors do not describe a systematic review itself, but we consider their paper is interesting because it summarizes seven research trends on the use of BCT in the BPM domain. These trends are related to: execution and monitoring systems on BC; methods of engineering process based on BC: redesigning processes; evolution and adaptation of business process: techniques which allow to identify, discover, and analyze relevant processes for the application of BC: knowing what is the impact associated with the implementation of BC in new business models: and understanding the cultural change that involves the use of this technology in business process execution as well as the contracting of services.

Lu [22] presents a survey which identifies future researches and highlighting open issues on blockchain. Author does not follow any systematic review method, and it just focuses on a paper published by IEEE. However, it is interesting to know how features of the blockchain (decentralization, openness and transparency, independence, safety, etc.) are supported by different researchers.

As mentioned above, authors summarize research trends [19] and open issues [22] on the use of blockchain technology, but they

have not identified the state-of-the-art on existing specific where techniques, tools or methods to improve collaborative BPM using BCT are presented.

Regarding weaknesses, Lu's paper does not follow any methodology (which hinders its reproducibility) and is only focused on papers published by IEEE. Both weaknesses are mitigated by our systematic review. On the one hand, our paper follows Kitchenham's methodology [24] which improves the objectivity of the results that have been obtained, as well as the reproducibility of our search protocol. On the other hand, our systematic review is applied on four digital libraries, which increases the probability of locating a significant sample of primary studies to be evaluated. In this sense, after performing our systematic review. our paper increases scientific knowledge of BCT applied to improve collaborative BPM.

Casino et al. [88] present a survey with the current state of the technological application of blockchain to different appli- cation domains. Specially, authors consider the economic application of BCT as an immovable aspect (cryptomoney and its management). For this purpose, authors review how the application of BCT produces an unprecedented B2C(Business to Consumer) and B2B (Business to Business) shift in online business processes. However, authors do not address or analyze implications, limitations or weaknesses of BCT when it is used to improve the management of these specific types of business processes. In addition, authors just focus on business processes related to economic applications.

Something similar happens in [89] and [90]. On the one hand, Hawlitschek et al. [89] conduct a systematic review of the existing literature on blockchain technology, but authors lack a broad perspective in the field of computer science. Authors consider only one topic for their study (i.e., <blockchain technology as a means of decentralized trust management in the business and social economy≫), but authors do not address the application of BCT to improve collaborative BPM. On the other hand, Seebacher and Schüritz [90] present a systematic review on BCT applied to software systems based on web services and processes. It does include the concept of supporting processes based on BCT as a possible aspect of BPM improvement into service-oriented architectures. However, authors indicate this possibility as a lesson learned after reviewing some previous works within following any methodological review process itself.

After analyzing previous related works, it is possible to conclude and summary that these papers are focused on topics related to BCT and some specific kind of business processes, but they do not provide an overview of the state-of-the-art on this technology and collaborative process management. In fact, these related works have not addressed the specific challenges and gaps of this topic. In this sense, therefore, our systematic review provides a

general point of view to analyze research papers that propose techniques, methods or tools to improve the inter-organizational process management using BCT. This analysis allows to identify gaps and open issues in this topic which has emerged repeatedly in recent years in the related works, but that none has explored in depth as a research objective.

III. PLANNING THE SYSTEMATIC REVIEW

One of most important possible aspects of any systematic review is to ensure its reproducibility and, for this purpose, it is necessary to define and plan its review process. This process includes the definition of the motivation to conduct this review, what are the research questions to be answered and the search protocol to perform, as well as quality assurance search criteria to apply. The planning stage also presents exclusion and inclusion criteria that are used to locate the most relevant primary studies. In this sense, it is also important to mention that filters on publication date have not been applied what allows to know all research production that has been published on our research subject. Next subsections describe in detail these aspects.

A. IDENTIFYING THE NECESSITY OF THE REVIEW

Over the last decade, many investigations are being carried out around the world to evaluate and identify challenges and obstacles to apply BCT on the field of Collaborative Business Processes (CBP). These researches have presented and evaluated blockchain technology in multiple processes and services of different business areas (logistics, supply chain, health, financial sector, etc.) what could have identified possible challenges and barriers of this technology to manage collaborative processes.

In this context, this paper systematically reviews the field of CBP in BCT domain in order to characterize and present opportunities and gaps for further research, as well as identify the nature of each primary study (i.e., academic prototype, application in industry, etc.).

B. FORMULATING RESEARCH QUESTIONS

According to Kitchenham's methodology, Research Ques- tions (RQ) are a mechanism that allows to focus any systematic review on specific topics. The objective is to improve scientific knowledge after analyzing research paper that are related to this topic. In this context, the systematic review described in this paper is guided by the following main research question: What is the state-of-the-art about the use of blockchain technology (BCT) to improve collaborative process management (CPM)?>. This main RQ has been divided into more specific RQ in order to offer more specific analysis and characterization of primary studies about BCT and CPM. These specific RQs and their motivations are described in Table 1.

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C. DEFINING THE REVIEW PROTOCOL

After establishing background and research questions to be answered, it is necessary to specify the review protocol to be carried out. For this purpose, this protocol defines aspects such as search strategy to find primary studies, what are selection criteria to select primary studies and what quality criteria will be applied on each primary study. These aspects are described in following subsections.

1) SEARCH STRATEGY

This section aims to describe the search procedure which are going to allow to locate relevant research to the improvement of CPM using BCT. For this purpose, papers related research papers published in journal and relevant conferences are going to be searched in various digital libraries following a two-stage strategy.

On the one hand, pre-searches are firstly performed to confirm the keywords to be used. These keywords improve the quality of the systematic review because these ones focus the location of research papers under study. Finally. Table 2 shows all keywords that have been used in this systematic review (some synonyms have been also considered to guarantee the inclusion of relevant papers).

On the other hand, after carrying out preliminary searches. and once keywords have been established, these keywords are combined to build search expressions, which are used to search primary studies in each digital library.

TABLE 1. Research questions.

Research Questions	Description
RQ1. What are the re existing approaches in the literature that use BCT in the domain of collaborative process management?	The objective of this RQ is to locate research papers that have published proposals to improve CPM using BCT. The motivation of this RQ is also to identify objectives and motivations of each primary study.
RQ2. What activities of BPM lifecycle are supported by each primary study and main contributions of each proposal? What is the nature of each primary study?	The objective of this RQ is to: (i) discover what activities (related to the BPM lifecycle) are supported by each primary study; and (ii) classify each primary study within the BPM lifecycle and describe main contributions of each proposal. The answer to this question must take account of clear pieces of evidence that are provided in each primary study considered in this SLR. This research question also aims to classify each primary study according to its own nature.
RQ3. What is research method applied to validate each primary study?	This research question determines the type of research method that is applied to validate each primary study.
RQ4. What are the business or industrial contexts where BCT is used to improve CBP management?	This RQ aims is to: (*i*) know main business and industrial contexts (such as, healthcare, manufacturing, supply Chains processes, etc.) where BCT is used to improve CBP management; and (*ii*) discuss specific industry applications.
RQ5. What are technical characteristics of each primary study?	The objective of this RQ is to identify technical characteristics of each primary study.

Moreover, some authors have established methodological criteria to select relevant digital libraries on which execute systematic reviews. For example, Ngai et al. [31] considers it relevant to use the following digital libraries: ABI Database, ScienceDirect, Academic Search Premier, Business Source Premier, ACM Digital Library, IEEE Xplore Digital Library. Science Direct, Springer, World Scientific Net and Web of Knowledge.

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TABLE 2. Keywords.

A	B	C
Collaborative Inter-Organizational	Business Process Process Management BPM Process Workflow	Blockchain

The construction of these expressions is mathematically formalized in Equation 1.

Mathematical expression to build search expressions using keywords.

$$E_1 = [(V_{i=1}^{2} A_i) \wedge (V_{j=1}^{4} B_j)] \wedge (V_{k=1}^{1} C_k) \quad (1)$$

However, after carrying out preliminary searches, it is possible to observe that many papers are simultaneously located in numerous of these libraries, what does not add new value to any systematic review but rather complicates the execution because it is necessary to discriminate more duplicate papers. This fact has been corroborated after executing the preliminary searches mentioned above.

In this context and considering these conclusions, fol- lowing digital libraries have been selected to execute and manage our systematic review: IEEE Xplore Library, ACM Library, Springer Link and ScienceDirect. It is also necessary to clarify that search expressions (formalized in Equation 1) are going to be applied on title-abstract-keyword metadata of each primary study according to the mathematical formula expressed in Equation 2.

Table 3 presents each search expression (Equation 2) that has been used on each digital library. It is important to clarify that some search expressions have been divided into several sub-expressions because of their excessive size (number of logical clauses). Some digital libraries do not support the use of long logical expressions to perform searches. For example, IEEE Xplore does not allow to indicate logical expressions with more than 15 logical clauses.

Finally, after automatically executing the search expres- sions (see Table 3) and, once papers under study are identified, the snowball>> technique is applied to extend the search process. In this sense, each reference used by each paper has been analyzed to identify other relevant papers related to our topic. The results of this strategy are in detail described in Section V.A.

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Digital Library		Query (Q)
ACM Digital Library	Q1	[[[Publication Title: "business process"] OR [Publication Title: "bpm"] OR [Publication Title: "process management"] OR [Publication Title: "collaborative business process"] OR [Publication Title: "collaborative process"] OR [Publication Title: "process"] OR [Publication Title: "collaborative bpm"] OR [Publication Title: "collaborative process management"] OR [Publication Title: "inter-organizational process"] OR [Publication Title: "inter-organizational bpm"] OR [Publication Title: "inter-organizational process management"] OR [Publication Title: "inter-organizational business process"] OR [Publication Title: "workflow"] OR [Publication Title: "collaborative workflow"] OR [Publication Title: "inter-organizational workflow"]] AND [All: "blockchain"]]
	Q2	[[[Abstract: "business process"] OR [Abstract: "bpm"] OR [Abstract: "process management"] OR [Abstract: "collaborative process"] OR [Abstract: "process"] OR [Abstract: "collaborative business process"] OR [Abstract: "collaborative bpm"] OR [Abstract: "collaborative process management"] OR [Abstract: "inter-organizational process"] OR [Abstract: "inter-organizational bpm"] OR [Abstract: "inter-organizational process management"] OR [Abstract: "inter-organizational business process"] OR [Abstract: "workflow"] OR [Abstract: "collaborative workflow"] OR [Abstract: "inter-organizational workflow"]] AND [All: "blockchain"]] OR [All:)) and] OR [[[Abstract: "business process"] OR [Abstract: "bpm"] OR [Abstract: "process management"] OR [Abstract: "collaborative process"] OR [Abstract: "process"] OR [Abstract: "collaborative business process"] OR [Abstract: "collaborative bpm"] OR [Abstract: "collaborative process management"] OR [Abstract: "inter-organizational process"] OR [Abstract: "inter-organizational bpm"] OR [Abstract: "inter-organizational process management"] OR [Abstract: "inter-organizational business process"] OR [Abstract: "workflow"] OR [Abstract: "collaborative workflow"] OR [Abstract: "inter-organizational workflow"]] AND [Abstract: "blockchain"]]
	Q3	[[Keywords: "business process"] OR [Keywords: "bpm"] OR [Keywords: "process management"] OR [Keywords: "collaborative business process"] OR [Keywords: "collaborative process"] OR [Keywords: "process"] OR [Keywords: "collaborative bpm"] OR [Keywords: "collaborative process management"] OR [Keywords: "inter-organizational process"] OR [Keywords: "inter-organizational bpm"] OR [Keywords: "inter-organizational process management"] OR [Keywords: "inter-organizational business process"] OR [Keywords: "workflow"] OR [Keywords: "collaborative workflow"] OR [Keywords: "inter-organizational workflow"]] AND [Keywords: "blockchain"]
IEEE Xplore	Q4	((((((((((((((("Document Title":collaborative process) OR "Document Title":process) OR "Document Title":BPM) OR "Document Title":collaborative BPM) OR "Document Title":process management) OR "Document Title":collaborative process management) OR "Document Title":collaborative business process) OR "Document Title":business process) OR "Document Title":Inter-Organizational process) OR "Document Title":Inter-Organizational BPM) OR "Document Title":Inter-Organizational process management) OR "Document Title":Inter-Organizational business process) OR "Document Title":Workflow) OR "Document Title":collaborative Workflow) OR "Document Title":Inter-Organizational Workflow)AND "Document Title":blockchain))
	Q5	((((((((((((((("Abstract":collaborative process) OR "Abstract":process) OR "Abstract":BPM) OR "Abstract":collaborative BPM) OR "Abstract":process management) OR "Abstract":collaborative process management) OR "Abstract":collaborative business process) OR "Abstract":business process) OR "Abstract":Inter-Organizational process) OR "Abstract":Inter-Organizational BPM) OR "Abstract":Inter-Organizational process management) OR "Abstract":Inter-Organizational business process) OR "Abstract":Workflow) OR "Abstract":collaborative Workflow) OR "Abstract":Inter-Organizational Workflow) AND "Abstract":blockchain))
	Q6	((((((((((((((("Author Keywords":collaborative process) OR "Author Keywords":process) OR "Author Keywords":BPM) OR "Author Keywords":collaborative BPM) OR "Author Keywords":process management) OR "Author Keywords":collaborative process management) OR "Author Keywords":collaborative business process) OR "Author Keywords":business process) OR "Author Keywords":Inter-Organizational process) OR "Author Keywords":Inter-Organizational BPM) OR "Author Keywords":Inter-Organizational process management) OR "Author Keywords":Inter-Organizational business process) OR "Author Keywords":Workflow) OR "Author Keywords":collaborative Workflow) OR "Author Keywords":Inter-Organizational Workflow) AND "Author Keywords":blockchain))

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TABLE 4. Description of exclusion and inclusion criteria.

Phase	Description of each inclusion and exclusion criteria
P1	This phase does not have exclusion criteria in themselves because its objective is to execute each search expression described in Table III. Therefore, all papers returned after executing these searches are considered in this phase.
P2	At this stage, different inclusion and exclusion criteria are applied. On the one hand, inclusion criteria are: (*i*) papers written in English and whose full content can be obtained; (*ii*) papers published in relevant forums, such as journals indexed in JCR (Journal Citation Reports) [33] or prestigious conferences categorized in CORE Conference Ranking [34]. Regarding CORE, conferences with A *, A and B level will be considered. On the other hand, papers not related to BCT and CPM are excluded.
P3	In this phase, duplicated papers are excluded, but the most comprehensive and recent paper always has priority. In addition, abstract, discussion, panel, surveys, tutorial, reviews or opinion papers are also excluded. This phase of exclusion considers the reading of full content of each paper. Any questions about any paper will cause the preliminary inclusion of this paper. The final decision will be considered and evaluated in the fourth phase.
P4	In this first meeting, relevant papers could be included, but there are no new exclusion/inclusion criteria are applied. In this phase also, all the doubtful papers are studied in detail, considering full content.
P5	Researchers apply the «snowball» technique in this phase using P2 criteria, as mentioned above.
P6	In this second meeting, all the doubtful papers (obtained from P5) are in detail studied to include relevant papers, but there are no new exclusion/inclusion criteria are applied.

TABLE 5. Quality questions.

#	Question & Scores
QQ1	Does the primary study describe what are the benefits and limitations of applying BCT technology to improve CPM? The possible answers are: Yes (+1); No (+0).
QQ2	Has the primary study been published in relevant conference (indexed in CORE Ranking [34]) or relevant journal (indexed in JCR index [33])? The possible answers are: A* or Q1 (+2); A or Q2 (+1.5); B or Q3 (+1); C or Q4 (+0.5); Unranked (+0).
QQ3	Does the paper describe which phase of BPM lifecycle it is supported and applied? The possible answers are: Yes (+1); No (+0).
QQ4	Is the paper validated with the scientific method? The possible answers are: Empirical validation applying experiment, survey or case study methods (+1); Unvalidated (+0).

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2) SELECTION PROCESS OF PRIMARY STUDIES

The selection process allows to standardize the identification of primary studies and it has been defined to integrate the participation of several different researchers who are jointly working on this systematic review. Specifically, this systematic review is carried out by two senior researchers and one junior researcher. In this context, six phases are proposed to uniformly and homogeneously execute this selection process. In addition, exclusion and inclusion criteria have been defined to be applied in each phase of the selection process. Table 4 summarizes these criteria.

At the ending, once fourth phase is finished, semifinal primary studies are obtained. These are preliminary because it is still necessary to apply the snowball technique>> (fifth phase; P5) on these semifinal studies to find new relevant studies. During the execution of this stage, it is also possible that some doubts arise when these new studies are considered by all researchers. In this sense, a second face-to-face meeting (sixth phase; P6) among all researchers is proposed to reach consensus on relevant papers and avoid subjective decisions.

3) QUALITY QUESTIONS

Quality Questions (QQ) allows to establish objective criteria to determine the quality of each primary study that is reviewed. Table 5 summarizes each quality question, which has associated scoring criteria (final quality score is going to be the cumulative score per quality question). It is important to mention that this quality score is not used to exclude primary studies, but to establish the relevance and representativeness of each primary study in future researches.

4) CHARACTERIZATION SCHEME

Each primary study that is analyzed in this systematic review may contain a wide variety of information, so, the analysis of this information could become a very tedious task. Table 6 defines a characterization scheme to reduce the effort required to carry out this task. The process for completing this scheme is based on two stages. Firstly, each researcher analyzes each primary study and complete the characterization scheme. Later, all researchers establish ordered discussions to agree on final data of this evaluation.

TABLE 6. Characterization scheme.

Feature	Description
Kind of publication	This feature means the forum where the approach has been published (i.e., journal, conference, or workshop).
Business area	It refers to the business area in which the approach has been applied.
Motivation and Description	This feature collects brief description of each primary study and its motivation.
Phase of BPM lifecycle	It means what is the phase in process management in which the proposal is focused.

5) EXTERNAL VALIDATION OF THE REVIEW PROTOCOL

Kitchenham's methodology recommends establishing mech- anisms to refine the search protocol of any systematic literature

review. The objective is to maximize the adequacy of this protocol with the objectives of the systematic review. In this sense, a couple of mechanisms have been proposed to carry out this review of the review protocol itself. Firstly, preliminary searches have been set up to adjust keywords, exclusion criteria and search expressions of this systematic review (as mentioned above; Section III.C.1). Secondly, an expert in conducting SLRs has been consulted to refine our review protocol. This person, who is Full professor in Software Engineering at University of Seville (Spain), proposed some changes, which have allowed to improve our review protocol.

IV. CONDUCTING AND QUALITY RESULTS

This section describes the execution of the review protocol that has been described in previous section. In this sense. on the one hand. Section IV.A presents the results of the selection process and statistical studies of these results. On the other hand. final primary studies that are considered in this systematic review are indicated in Section IV.B. This last section also includes the quality score of each primary study after applying the characterization scheme on each one (see Table 5). Finally, some threats may have occurred during the review process. These aspects are also discussed in Section IV.C.

A. EXTRACTION AND DETECTION OF PRIMARY STUDIES

After applying search queries described above, our selection process and inclusion/exclusion criteria have been applied. Figure 1 illustrates the complete process of selecting the primary studies and Table 7 summarizes the distribution of research papers that have been analyzed in this selection process.

TABLE 7. Characterization scheme.

Database	P1	P2	P3	P4	P5	P6
ACM	94	14	6	1	-	-
IEEE Xplore	649	65	23	8	-	-
ScienceDirect	91	21	12	5	-	-
SpringerLink	300	31	15	10	-	-
Snowball technique	0	0	0	0	56	10
Subtotals	1134	131	56	24	56	10
TOTAL	**34**					

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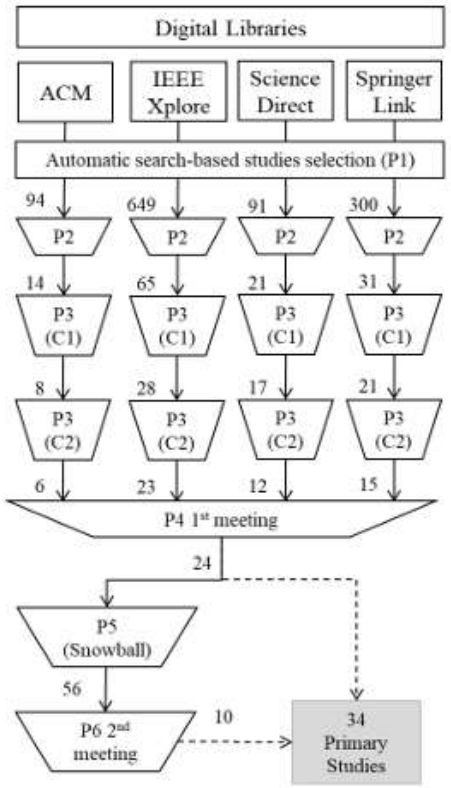

FIGURE 1. Summary diagram of the selection process of primary studies.

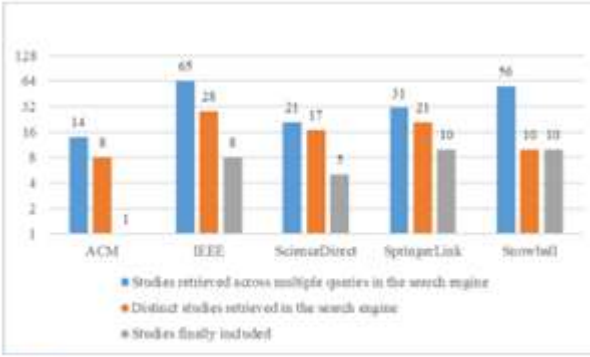

FIGURE 2. Studies retrieved through search engines.

Firstly, after finishing the first phase of the selection process, 1134 candidate papers have been found (see Table 7). These candidate papers have been returned after executing each search expression (Table 3) on each digital library. Secondly, exclusion criteria have been applied in the second phase (P2), which returns 131 candidate research papers and is considered the first milestone of our review protocol. Figure 2 shows this milestone in the first data series of the histogram. Specifically, this series represents papers that are retrieved from each digital library after executing all search expressions.

Subsequently, the next executed phase (P3; third phase) returns 56 candidate research papers when this one has finished. These results are the second milestone of the search protocol and are associated with the second data series of the histogram (Figure 2). This series means the number of primary studies that are obtained from each digital library after deleting duplicate papers. Furthermore, these results also exclude research papers related to comparative studies, systematic mapping studies, surveys, systematic literature reviews, and opinion articles, among others.

Moreover, Figure 3 shows the distribution of primary studies that are retrieved in each digital library with respect to the total of selected studies of all the search engines. It is interesting to note that Springer provides 42 % (approx.) of primary studies and most digital libraries include 10% (approx.) of the studies. This fact can be observed of the second value of the series shown in Figure 3. This value presents primary studies that are finally considered in the analysis and retrieved from the digital library divided by all the different primary studies that are been retrieved from the same digital library.

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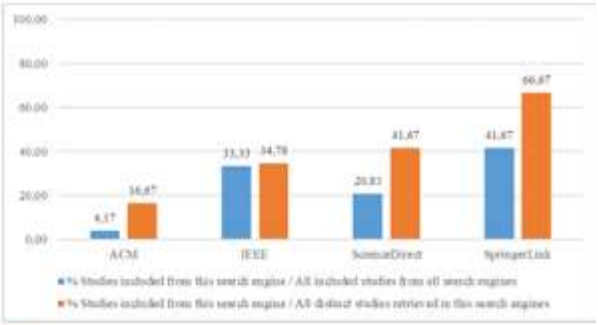

FIGURE 3. Analysis of retrieved results from digital libraries respect to total final primary studies.

B. THREATS IN THE VALIDATION

The existence of threats is an inherent fact when any task has been carried out by people. In this sense, it is possible to identify some threats associated with the selection process and the validation process that have been executed in this paper. For instance, some mistakes could have appeared during selection of primary studies or data extraction. However, our selection process (Section III.C.2) has been planned in well-controlled phases to minimize this risk. Furthermore, several reviews and meetings between researchers have also been carried out to reduce this risk.

V. ANALYSIS

A. RQ1. WHAT ARE THE EXISTING APPROACHES IN THE LITERATURE THAT USE BCT IN THE DOMAIN OF COLLABORATIVE PROCESS MANAGEMENT?

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TABLE 8. Primary studies and their quality assessment score.

Primary studies	Authors and title	Scores (max.6)	Ref.
[P1]	C.Yuanyuan; W. Hui; L. Xuefeng: Improving Business Process Interoperability by Shared Ledgers.	0,00	[36]
[P2]	S. Chen; R. Shi; Z. Ren; J. Yan; Y. Shi; J. Zhang: A Blockchain-Based Supply Chain Quality Management Framework.	0,75	[37]
[P3]	A. Kapitonov; I. Berman; S. Lonshakov; A. Krupenkin: Blockchain Based Protocol for Economical Communication in Industry 4.0.	1,00	[38]
[P4]	O. López-Pintado; L. García-Banuelos; N. Dumas; I. Weber: Caterpillar: a blockchain-based business process management system.	4,50	[39]
[P5]	W. Viriyasitavat; D. Hoonsopon: Blockchain characteristics and consensus in modern business processes.	2,00	[40]
[P6]	C. Prybila; S. Schulte; C. Hochreiner; I. Weber: Runtime verification for business processes utilizing the Bitcoin blockchain.	3,50	[41]
[P7]	C. Shuchih; C. Yi-Chian; L. Ming-Fang: Supply chain re-engineering using blockchain technology: A case of smart contract based tracking process.	1,00	[42]
[P8]	W. Viriyasitavat; L. XuZhuming; B. Assadaporn: Blockchain-based business process management (BPM) framework for service composition in industry 4.0.	2,00	[43]
[P9]	D. Silva; S. Guerreiro; P. Sousa: Decentralized Enforcement of Business Process Control Using Blockchain.	2,00	[44]
[P10]	M.F. Madsen; M.Gaub; T. Hgnason; M.E. Kirkbro; T. Slaats; S. Debois: Collaboration among adversaries: distributed workflow execution on a blockchain.	2,00	[45]
[P11]	I. Weber; X. Xu; R. Riveret; G. Governatori; A. Ponomarev; J. Mendling: Untrusted Business Process Monitoring and Execution Using Blockchain.	4,50	[46]
[P12]	D. Karastoyanova; L. Stage: Towards Collaborative and Reproducible Scientific Experiments on Blockchain.	1,50	[47]
[P13]	L. García-Bañuelos; A. Ponomarev; M. Dumas; I. Weber: Optimized Execution of Business Processes on Blockchain.	4,50	[48]
[P14]	C. Sturm; J. Szalanczi; St. Schonig; S. Jablonski: A Lean Architecture for Blockchain Based Decentralized Process Execution.	4,50	[49]
[P15]	G. Falazi; M. Hahn; U. Breitenbcher; F. Leymann: Modeling and execution of blockchain-aware business processes.	3,00	[50]
[P16]	X. Liang: Blockchain Based Provenance Sharing of Scientific Workflows.	2,00	[51]
[P17]	H. Nakamura; K. Miyamoto; M. Kudo: Inter-organizational Business Processes Managed by Blockchain.	4,00	[52]
[P18]	C. Di Ciccio; A. Cecconi; J. Mendling; D. Felix; D. Haas; D. Lilek; F. Riel; A. Rumpl; P. Uhlig: Blockchain-based traceability of inter-organisational business processes.	2,00	[53]
[P19]	O. López-Pintado; M. Dumas; L. García-Bañuelos; I. Weber: Interpreted Execution of Business Process Models on Blockchain	4,00	[25]
[P20]	D. Fernando; S. Kulshrestha; J. D. Herath; N. Mahadik; Y. Ma; C. Bai; P. Yang; G. Yan; S. Lu: SciBlock: A Blockchain-Based Tamper-Proof Non-Repudiable Storage for Scientific Workflow Provenance	1,00	[26]
[P21]	M. Li; G. Q. Huang: Blockchain-enabled workflow management system for fine-grained resource sharing in E-commerce logistics	2,00	[27]
[P22]	N. Bore; A. Kinai; J. Mutahi; D. Kaguma; F. Otieno; S. L. Remy; K. Weldemariam: On Using Blockchain Based Workflows	1,00	[28]
[P23]	F. Panduwinata; P. Yugopuspito: BPMN Approach in Blockchain with Hyperledger Composer and Smart Contract: Reservation-Based Parking System	1,00	[29]
[P24]	G. Fridgen; S. Radszuwill; N. Urbach; L. Utz: Cross-organizational workflow management using blockchain technology - towards applicability; auditability; and automation	3,50	[74]
[P25]	Y. Fang; X. Tang; M. PanYang Yu: A Workflow Interoperability Approach Based on Blockchain	3,00	[75]

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TABLE 9. Distribution of primary studies related to activities of BPM lifecycle (Dumas *et al.* [63]) and types of proposals.

Primary studies	Activities of BPM lifecycle							Types of Proposals						
	A1	A2	A3	A4	A5	A6	A7	T1	T2	T3	T4	T5	T6	T7
[P1]		○		○	○	○		☒	☒					
[P2]					○			☒	☒					
[P3]					○				☒					
[P4]		⊙			⊙									☒
[P5]		⊙			⊙			☒	☒					
[P6]			⊙					☒		☒				☒
[P7]			○						☒			☒		
[P8]			⊙					☒	☒	☒				
[P9]		⊙			⊙			☒				☒		☒
[P10]			⊙		○			☒						☒
[P11]		⊙			⊙			☒		☒				☒
[P12]					○			☒						
[P13]		⊙								☒				
[P14]					⊙			☒						☒
[P15]		⊙						☒		☒				☒
[P16]		⊙						☒						
[P17]		⊙						☒		☒				
[P18]			⊙		○			☒						☒
[P19]				⊙			⊙							☒
[P20]			⊙		○									☒
[P21]					○									☒
[P22]					○			☒						☒
[P23]		○						☒		☒				
[P24]					○			☒						☒
[P25]		○						☒	☒	☒				
[P26]		⊙						☒	☒			☒		☒
[P27]		⊙			⊙			☒		☒		☒		☒
[P28]		⊙			○									☒
[P29]					⊙			☒	☒	☒				
[P30]					⊙			☒						☒

VI. CONCLUSION AND OPEN ISSUES

BlockChain Technology (BCT) has emerged as new tech- nology and offers valued cost reductions by enabling transactions to be executed in a peer-to-peer manner directly between entities or individual users, without delegating trust to central official authorities nor requiring mutual trust between each couple of parties. These features have led to a rapid and growing attention on BCT within different contexts; for instance, BPM [73]. In fact, it is possible to see the interest of public bodies, scientific community and software industries to know the feasibility and opportunities that BCT offers to improve collaborative process management in a decentralized manner. In this context, a systematic review is presented in this paper, which identifies and analyses the state-of-the-art of research papers about collaborative BPM in BCT domain. For this purpose, Kitchenham's method has been followed, what allows to locate different types of proposals that address the CBP management using BCT. Specifically, 34 primary studies have been identified once the search protocol described in this paper has been executed. These studies have been also classified according to the activities of the BPM lifecycle to which they offer support. For this purpose, Dumas' BPM lifecycle has been used to perform this classification. After carrying out this review, open issues have been identified.

On the one hand, there is a lack of proposals that provide support for the first and last activity of the Dumas' lifecycle, that is, «Al-Identification» and «A7 Adaptation>>> activities (these ones are supported by 0 and 1 proposals, respectively). This situation is an opportunity for innovation for the research community to be pioneers in this field. This also occurs in «A4 - Redesign>> and <A6- Monitoring>>> activities (both ones are supported by 4% and 1% of primary studies, respectively). Although it has been possible to find one primary study ([PI]) with support for these activities, authors only describe good intentions of their proposal, and it does not provide any evidence of this support either. In this sense, it is also a relevant opportunity to be investigated to improve the modeling of processes using patterns. On the other hand, it is possible to establish some

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