# Literature Review Linking Blockchain and Business Process Management

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**Abstract.** Blockchain Technology emerged recently in the area of Business Process Management and is still in its infancy. This paper analyses and evaluates the current scientific literature on the subject matter and synthesizes common topics, in order to create an understanding of the status quo. In a structured literature review, more than 300 publications were identified, of which 24 were finally selected as relevant to the cross-sectional topic of Blockchain and Business Process Management (BPM). A quantitative analysis affirms the recent upcoming of the relatively young research field and narrows the identified papers into three topic clusters, namely application areas and challenges, process architecture and design, and process execution related publications.

Keywords: Literature Review, Blockchain, Business Process Management

## 1 Introduction

Blockchain technology can facilitate business process execution and crossorganizational collaboration in an automated manner, without the reliance on third parties [1]. In typical collaboration scenarios between businesses, process integration is mediated with the help of these third parties [2]. The Blockchain's immutability and transparency allow business partners or regulatory bodies to audit process steps at any time. The data recorded from these business processes is available permanently and with the certainty, that no modifications have been made. The technical capabilities of Blockchains can further help in solving the trust issue faced by companies engaging in shared business practices, since tamper-proof records of transactions are in place.

The contribution of this paper is to analyze and evaluate the current technical Blockchain solutions applicable to BPM, as depicted in the scientific literature. By conducting a systematic literature review, publications until April 2019 dealing with the intersection of business processes and Blockchain technology, are identified.

One topic identified during the search process deals with the design principles for modeling processes on the Blockchain. The execution of processes with the help of Business Process Engines and the transformation of processes into code, based on Business Process Model and Notation (BPMN) diagrams, is a further topic. In addition,

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the challenges, which are limiting the adoption of Blockchain technology for BPM are highlighted.

# 2 Background

### 2.1 Blockchain

Blockchain technology can be interpreted as a sub-section of Distributed Ledger Technology. At the highest abstraction level, a distributed ledger is a store of transactions, distributed among multiple machines with specific constraints. One such constraint is the append-only nature of data storage. Once a transaction is successfully validated and stored, modification or deletion of that transaction is disallowed. Each block in the Blockchain is structured as a linked list, with each item in the list symbolizing a block. Each of these blocks can contain a limited amount of ordered transactions, depending on the maximum block size. Transactions trigger state transitions, which are then verified by cryptographic hash functions. Should the content of any block be modified, its hash value would change fundamentally and since this hash value is stored in the head of the following block, the resulting inconsistency would lead to a rejection of operations. The legality of state transitions is decided based on the respective consensus rules agreed upon in the network. The distributed network into which new transactions are propagated and new blocks formed, is based on a standardized peer-to-peer protocol. For this paper, we focus mainly on Blockchains offering smart contracts.

Research of the future potential of this technology envisions many areas of application, several of which concern the corporate context. As corporations can be mandated by law to enforce privacy, or have an economic incentive to keep data on e.g. their processes private, several types of Blockchain can be of interest. There are public Blockchains, consortium Blockchains and non-public (private) Blockchains [3]. With public Blockchains, anyone can access the entire full node, a copy of the complete linked list, view all stored data and participate to formulate a consensus. In consortium Blockchains, the control of a node are determined in advance by central authorities. It is determined which participants have the right to read, or write into the Blockchains are systems that are only available for a closed group, such as organizations, for which access rights are administered.

Smart contracts are programs in the form of data stored in the Blockchain, which can be executed through interactions in the form of transactions. Smart contracts can manage digital assets and invoke other smart contracts through function calls [4]. Since these contracts, once deployed, are immutable and deterministic, their behavior is predictable and transparent. Immutability refers to the finality of transactions, once accepted as the correct state by consensus. Code is deterministic, since it executes in exactly the same manner across multiple machines. The deployed code is translated into bytecode, which is to be executed by the Ethereum Virtual Machine (EVM). The EVM can be thought of as a global decentralized computer with several millions of lines of permanent data storage [5]. There are three reasons to carry out transactions in the Ethereum network: to create a new smart contract, to call a function of an existing smart contract or to transfer cryptocurrency. These transactions are then stored in the Blockchain, in order to reflect the status of each contract and the credit balance of each participant in the network.

#### 2.2 Business Process Management

A business process is a sequence of activities that transform an input into an output in order to do justice to the interests of customers and stakeholders [6].

Rosemann and vom Brocke introduced the Business Process Management Maturity Model (BPMMM) [7], which is a consolidating framework providing structure and decomposing BPM into core elements. The framework is visually represented in a matrix shown in Fig. 1. Accordingly, there are six factors into which BPM can be divided in a company. These are strategic orientation, leadership, methods, information technology, people and culture, whereby each factor is again subdivided into five skill areas. In the context of this paper, it is necessary to narrow the scope to the fields outlined in black in Fig. 1. The main focus areas fall into the realm of Information Technology and Methods. Methods are defined as a set of tools and techniques supporting and enabling activities along the process lifecycle. Information Technology as a factor in BPM is similar to Methods in that it enables and supports the process lifecycle. Process design & modelling is used to identify and conceptualize the as-is and to-be process landscape. Process implementation & execution allows for automated transformation of process models into executable specifications and workflow-based process implementation. Process Monitoring & Control refers to any activities aiding in the collection and consolidation of process related data.

Strategic Alignment	Governance	Methods	Information Technology	People	Culture	Factors
Process Improvement Planning	Process Management Decision Making	Process Design & Modelling	Process Design & Modelling	Process Skills & Expertise	Responsiveness to Process Change	
Strategy & Process Capability Linkage	Process Roles and Responsibilities	Process Implementation & Execution	Process Implementation & Execution	Process Management Knowledge	Process Values & Beliefs	Capa
Enterprise Process Architecture	Process Metrics & Performance Linkage	Process Monitoring & Control	Process Monitoring & Control	Process Education	Process Attitudes & Behaviors	ability /
Process Measures	Process Related Standards	Process Improvement & Innovation	Process Improvement & Innovation	Process Collaboration	Leadership Attention to Process	Areas
Process Customers & Stakeholders	Process Management Compliance	Process Program & Project Management	Process Program & Project Management	Process Management Leaders	Process Management Social Networks	

Figure 1. Factors and capabilities of BPM according to [7]

# 3 Methodology

### 3.1 Literature Review

The main question of this paper can be summarized to: *What is the current state of research that links Blockchain Technology with Business Process Management?* BPM is a far-reaching field covering many sub-topics. We focus on execution aspects of business processes with the help of Business Process Engines (cf. Fig. 1). In particular, execution of processes in inter-organizational settings is of particular interest. The structure of this paper is aligned to the method of [8]. Accordingly, the systematic literature analysis is divided into five steps: (1) define the scope and extent of the work, (2) conceptualize the topic, (3) perform the search. (4) analyze and evaluate the literature and finally (5) develop a research agenda for future studies.

### 3.2 Research Focus

Characteristics	Categories								
Focus	Results			Methods	Theor		ries	Applications	
Goal	Synthesis	C	ritic	cal Analysis	Ic	Identification of Central Issues			
Perspective	Neutral Representation					Espousal of Position			
Coverage	Exhaustive	Exhaustive Selective			е	Representati		ive	Pivotal
Organization	Historical		Conceptual		.1	Methodological			
Audience	Specializ. Scholars Ge		eneral Scholars		Practitioners		General Public		

Table 1. Taxonomy of specific literature review characteristics

To determine the scope and extent of this work, a scheme developed by Cooper [9] is applied, which can be seen in Table 1. The fields highlighted in grey are the categories that this paper will focus on. The focus of literature reviews can be divided into four self-explanatory categories: results, methods, theories and applications, all of which are considered. As regards goals, the literature is synthesized, and central problems of Blockchain in BPM are identified. In terms of coverage only papers applicable to both Blockchain and BPM are included. Conceptual reviews group literature based on similar ideas, methodological literature analyses literature according to the methods used, both of which we will utilize. This paper is aimed at specialized professionals and scholars but may also be of interest to practitioners.

#### 3.3 Conceptual Refinement

The next step is to develop a concept regarding what is already known about the topic [8, 10]. A concept map (cf. Fig. 2) creates a basic understanding of the topic. The concepts and synonyms shown in the diagram also serve as a basis for the development of the keywords used in the later literature search on BPM and Blockchain.



Figure 2. Concept map for key search strings

#### 3.4 Search Method and Selection Procedure

After the scope of this review has been defined and the topic conceptualized, we initiate the search for literature. For this purpose, vom Brocke et al. [8] have developed a procedure consisting of four phases. These are separated into searches for (1) journals, (2) databases, (3) keywords and (4) the forward/backward search.

Phase one includes the search for suitable journals and conferences. Among the highest rated journals and conferences with diverse releases are the "Business Process Management Journal" (BPMJ) and the "International Conference on Business Process Management" (BPM). The conferences "International Conference on Information Systems" (ICIS), "European Conference on Information Systems" (ECIS) and "Americas Conference on Information Systems" (AMCIS) are included as well.

Five databases were identified in the second phase, all of which are assumed to be widely known by the target audience of this paper, and deeper analysis is hence omitted.

In the third phase, keywords are identified. These are largely derived from the conceptualization of the topic in chapter 3.2 of the concept map, both singular and plural. The keywords and resulting paper quantity can be seen in Table 2. The specific search operators are adapted based on the database according to documentation. In total, 300 articles were found (plus 44 duplicates). Titles were analyzed to sort for relevant hits, resulting in 53 remaining papers.

After reading through each abstract and further parts of these 53 papers, 32 papers remained, which were used in the fourth phase to perform a forward and backward search, finding 13 more relevant articles. This brings the number of papers relevant to this literature review to 45. The complete literature search is shown in Fig. 3.

The inclusion criteria were the following: (1) studies with an intersection between Blockchain and BPM, (2) studies describing approaches to model business processes on the Blockchain, (3) studies explaining the technical implementation of business processes on the Blockchain.

The exclusion criteria were the following: (1) studies focused on extraneous topics not related to the focus of the study, (2) any duplicate papers.

As regards data synthesis, a qualitative analysis was conducted to evaluate crosssectional factors, followed by a quantitative analysis for keywords and their prevalence. Finally, an analysis of the topic's history and the chronology of papers was conducted.

Database	Keywords			
Emerald	(Blockchain OR "Distributed Ledger Technolog*" OR Ethereum OR "Smart Contract*") AND ("Business Process" OR "Business Process Management" OR "Business Process Management System*" OR "Business Process Execution" OR "Business Process Engine*" OR "Choreograph*" OR "Inter-organizational" OR BPM OR BPMS OR BPE)	52		
Springer Link	(Blockchain OR "Smart Contract*" OR "Distributed Ledger Technolog*" OR Ethereum) AND ("Business Process Management" OR Choreograph* OR "Busi-ness Process Engine*" OR "Business Process Execution" OR "Business Process Management System*" OR "Inter-organizational" OR BPM OR BPE OR BPMS)	167		
AISeL	(Blockchain OR "Smart Contract*" OR "Distributed Ledger Technolog*" OR Ethereum) AND ("Business Process Management" OR Choreograph* OR "Busi-ness Process Engine*" OR "Business Process Execution" OR "Business Process Management System*" OR "inter-organizational" OR BPM OR BPE OR BPMS )	46		
EBSCO	(Blockchain OR "Smart Contract*" OR "Distributed Ledger Technolog*" OR Ethereum) AND ("Business Process" OR"Business Process Management" OR Choreograph* OR "Business Process Engine*" OR "Business Process Execution" OR "Business Process Management System*" OR "Inter-organizational")	20		
Web of Science	TI=((Blockchain OR "Distributed Ledger Technolog*" OR Ethereum OR "Smart Contract*") AND (Business OR "Inter-organizational" OR Choreograph*)) OR TS=((Blockchain OR "Distributed Ledger Technolog*" OR Ethereum OR "Smart Contract*") AND (Business OR "Inter-organizational" OR Choreograph*)	59		
Σ		344		





Figure 3. Search process for relevant articles

# 4 Analysis and Evaluation

#### 4.1 Quantitative Analysis

The literature developed in the previous chapter is analyzed according to criteria by [8]. In order to gain an initial understanding of the topic Blockchain in the Business context, the most frequently occurring keywords are displayed in Fig. 3.

From Fig. 3, it can be seen that all keywords, except service and supply chain, can be divided into the two overarching concepts Blockchain and BPM. In addition to examining the keywords, we examine the publication years in the quantitative analysis. These are shown in Fig. 4.



Although Blockchain entered the public perception in 2008, it was not until 2016 that scientists began to address the issue of executing business processes between several process participants using Blockchain Technology [11, 12]. The cutoff to literature search was the end of April 2019, hence the steep decrease in Fig. 4. As regards the analysis of publication channels, 18 publications originate from journals, 23 originate from conferences and 4 are found as chapters within books.

All 45 sources have been assessed using the VHB-JOURQUAL 3<sup>1</sup> ranking to assess overall publication quality. Three items were rated 'B', twelve were rated 'C'. The remaining 30 were either unrated, or not included. Reasons for a lack of peer-reviewed output in top ranking journals may be due to the chosen ranking scheme, the infancy of this research area, longer review cycles top-outlets, at the same time a short practical observation period and strong empirical requirements for 'A'-ranked publications.

### 4.2 Qualitative Analysis

All final articles were examined in detail, wherein papers only superficially dealing with the research topic were further eliminated, leaving 24 of the original 45 articles. The research may be grouped into three major topic clusters.

#### a) Application Areas and Challenges

Five publications focus on summarizing challenges, solution approaches or potentials of the Blockchain in the execution of business processes. Accordingly, there

<sup>&</sup>lt;sup>1</sup> https://vhbonline.org/vhb4you/jourqual/vhb-jourqual-3/teilrating-wi/

are still six major challenges to be solved before the technology can be used on a large scale in business, such as scalability and cost [1]. Confidential data, which is necessary for the execution of certain processes can be viewed by everyone and hence privacy laws might be violated, or internal process data leaked to unwanted actors [13].

As for potentials, Blockchain technology offers the possibility to model interorganizational processes in the same way as intra-organizational processes [14]. These processes can then be integrated into the business process using systems such as Caterpillar. Viriyasitavat and Hoonsopon develop and architecture that contains the key technologies and framework conditions to execute business processes on the Blockchain [15]. The central element of this architecture is the Practical Byzantine Fault Tolerance (PBFT) consensus with smart contracts. Smart contracts are readable for machines and interpretable in a deterministic and unambiguous manner, unlike traditional contracts, highlighted by [11].

#### b) Process Design for Blockchain-based Architecture

Seven articles focus on the modeling of business processes on the Blockchain. One publication develops an integration architecture that abstracts the functions of a public Blockchain and thus allows external applications, such as process engines, to communicate with the Blockchain [16]. Further work identifies two approaches for combining choreographies with Blockchain platforms [17]. Firstly, the Blockchain serves as an account book, storing information for reproducing collaborative experiments. Secondly, smart contracts are used to perform choreography and workflows. In the next publication, a Blockchain-based compliance model allowing automated enforcement of compliance in a large company, distributed over several countries, is investigated [18]. In turn, auditing endeavors are simplified and can be retroactively applied. One publication presents a framework system that enables users without in-depth IT knowledge to execute business rules as smart contracts on the Hyperledger Blockchain, based on the Business Collaboration Rules Language (BCRL) [19]. In further work, an artifact consisting of a Unified Modeling Language class diagram is designed for a meta model, examining the mapping between business transactions and the Blockchain [20]. The Design and Engineering Methodology (DEMO) is discussed in [21]. Therein, smart contracts are created from DEMO models and a blockchain software architecture is developed. Conceptualization of enterprise models is supported in a decentralized manner in a further publication [22]. Within, a model for inter-organizational business processes is formed and the monitoring processes through metadata is supported.

#### c) Process Execution on Blockchain

12 articles regard the technical execution of business processes on the blockchain. The Open-Source Business Process Management System Caterpillar supports the creation of instances from a process model and allows the user to track the intermediate status of process instances and execute tasks. Caterpillar runs on the Ethereum Blockchain and the workflows are executed by smart contracts, themselves generated with a BPMN-to-Solidity compiler [23]. Building on this is a BPMS on the Blockchain that handles collaborations between organizations [24]. In addition, the authors

developed a model for the dynamic role assignment of participants in collaborative processes, and the associated Binding Policy Specification Language (BPSL) [25]. The Lorikeet tool was developed to implement business processes on the Blockchain, for the purpose of managing assets. Lorikeet can automatically create smart contract code from specifications set in a business process [26]. The immutability of the Blockchain allows participants to compute and store a transparent history of decision making, creating a reliable and verifiable basis for the storage an essential business processes steps [27]. Alternatively, transaction history can be read by lookups of hash values, generated through smart contracts and stored in the ledger [28]. Leveraging techniques that transform business process models into state transition diagrams for process participants on Blockchains, is another use case [29]. The initialization cost of process instances, the cost of executing a task using a space-saving data structure, and improved run-time components for maximum throughput are provided by [30]. The cost of running business processes is compared to traditional cloud services by calculating the costs of smart contract execution and storage of transactions, to determine a cost model [31]. As regards trust, choreography of processes is structured in such a way, that it requires no trusted third party [12], which is further analyzed as regards the confidential handling of data during the execution of a business process [32].

# 5 Conclusion

This paper analyses and evaluates scientific literature and performs a synthesis, in order to create an understanding of the status quo. During this process, we identified more than 300 recent publications related to our search string linking the topics Blockchain and BPM, of which 24 were finally selected as relevant. A quantitative analysis affirms an emerging trend in the cross-sectional research topic in the last three years. The qualitative analysis then identifies and clusters the relevant papers into three topic groups, namely application areas and challenges, process architecture and design, and process-execution-related publications.

The opportunities created for BPM by Blockchain technology are vast, but research regarding the practical applicability in real world scenarios is still limited. Our findings show that a large degree of literature is concerned with prototypical implementations and theoretical constructs that have yet to be deployed in actual business processes. Despite this fact, analysis of the technological status reveals a wide degree of business process architecture models, that may be implemented on Blockchains, mostly based on Ethereum.

Our findings indicate a clear lack of privacy-related articles in the researched field. While privacy solutions already exist [33, 34], they are constrained in their applicability or cost and come with major limitations leading to a trade off in the design of smart contracts. Future research should address this topic more thoroughly. Also, promising developments in the analysis of smart contract event logs for subsequent process mining of Blockchain systems are already evident [35].

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