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*Review*

# Blockchain and Business Process Management (BPM) Synergy: A Comparative Analysis of Modeling Approaches

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**Abstract:** Blockchain technology has become a powerful disruptive force that upends established ideas in several industries. A fascinating point of convergence is that of blockchain technology and Business Process Management (BPM), where the distributed and immutable characteristics of blockchain promise to completely transform the modeling, implementation, and oversight of business processes. This symbiosis offers a singular chance to develop corporate processes that are more efficient, safe, and transparent. Nevertheless, to guarantee that blockchain-specific components are accurately represented in these processes, modeling techniques need to be critically examined as part of integrating blockchain into BPM. This literature review examines blockchain-BPM integration using different modeling methodologies. Though well-established, traditional BPM approaches may need help with blockchain-specific aspects. Blockchain-oriented modeling includes smart contracts and decentralized consensus. Hybrid models with blockchain and traditional elements are popular. Adaptability, model clarity, and blockchain integration are evaluated in the analysis. This literature review aims to improve corporate processes' efficiency, security, and transparency by investigating how to model the integration of blockchain and BPM better.

**Keywords:** blockchain-BPM integration; distributed and immutable characteristics; modeling techniques examination; hybrid models in BPM



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## 1. Introduction

A decentralized and revolutionary system, blockchain technology records and verifies transactions securely across a network of computers [1,2]. The system functions as a decentralized ledger in which every node or network participant upholds an exact duplicate of the complete ledger [3]. Each block in the sequence of blocks that constitutes this ledger contains a list of transactions. The primary innovation of blockchain technology lies in its capacity to guarantee immutability, security, and transparency in the ledger of transactions. Blocks are formed from transactions, which are connected via cryptographic hashes. Because modifications to a single block would necessitate alterations to all succeeding blocks, the blockchain is impervious to fraud and tampering [4,5].

A consensus mechanism ensures that all blockchain nodes concur on the validity of transactions before their inclusion in the ledger. Prominent consensus mechanisms consist of Proof of Work (PoW) and Proof of Stake (PoS), both of which possess distinct merits and demerits [6]. A feature of blockchain that is fundamentally different is its implementation of smart contracts, which are contracts that execute themselves and contain pre-programmed terms and conditions [7]. There are implications for blockchain technology beyond cryptocurrencies, which was its initial use case. There is a growing trend of integrating it into diverse sectors such as finance, supply chains, healthcare, and others [8,9]. Blockchain's decentralized and tamper-resistant characteristics can augment confidence, mitigate fraudulent activities, and optimize workflows across diverse sectors.

Integrating blockchain technology and Business Process Management (BPM) has extensive ramifications that profoundly transform the complexities of modern business activities.

At its core, blockchain's decentralized and tamper-resistant architecture fosters transparency in business operations by establishing an immutable repository of truth [10,11]. By facilitating a secure and verifiable ledger of transactions, this integration instills trust and assurance among stakeholders, particularly in scenarios involving many participants. By integrating smart contracts into BPM, contract enforcement and execution are further automated, accelerating transaction processes and decreasing the likelihood of errors [12–14]. The integration of transparency and automation has the potential to profoundly alter how various industries address concerns related to operational efficiency and trust [15,16].

Ensuring security is of the utmost importance in modern business environments; this is precisely why the integration of blockchain with BPM can be used to safeguard transactions and data via cryptographic techniques [17,18]. By utilizing blockchain in conjunction with BPM, data are distributed across the network in a decentralized fashion, reducing the likelihood of a single point of failure and increasing the process's overall resilience [19,20]. Moreover, the audit trail generated by the blockchain's immutability is impervious to manipulation, which is of immense value in sectors governed by rigorous regulatory standards [21,22]. In addition to enhancing security measures, this integration facilitates cost reductions by eliminating superfluous intermediaries and promoting operational efficiency through streamlined processes [23]. The convergence of blockchain technology and BPM improves established business procedures and stimulates the development of novel paradigms, thereby serving as a transformative catalyst for the future of business operations [24].

Numerous scholarly investigations have examined the interplay between blockchain technology and BPM, highlighting the prodigious possibilities for cooperation and empowerment across diverse sectors. To resolve the challenges in this field, a BPM-based framework for assessing the impact of blockchain on the midstream liquefied natural gas (LNG) supply chain has been proposed [25]. Furthermore, scholarly investigations have been undertaken to devise secure business procedures for blockchains, underscoring the potential for enhanced privacy and security [26,27]. Prior research has explored the potential partnership between big data and blockchain technologies within BPM, focusing on the groundbreaking transformations that could occur [28]. Even with the extant body of research, a comprehensive literature analysis of diverse modeling approaches about the synergy between blockchain and BPM remains a research lacuna. A literature review would yield significant insights regarding the merits and drawbacks of diverse modeling methodologies, thereby enabling the discernment of the most appropriate strategies for various application scenarios.

By providing insights into the challenges and opportunities of integrating blockchain into BPM, conducting a literature review of existing modeling methodologies, and proposing criteria for evaluating the success of such integration efforts, this paper contributes to the scientific community. Researchers, practitioners, and decision-makers who wish to comprehend and implement blockchain-driven business process transformations will find this work valuable.

## 2. Modeling Approaches in Blockchain and BPM Integration

Blockchain technology has garnered considerable interest within BPM because of its capacity to augment business process transparency, security, and efficacy. Several modeling approaches are utilized in integrating blockchain and BPM to optimize and align business processes with the capabilities of blockchain technology. One potential strategy involves converting Business Process Model and Notation (BPMN) models into blockchain smart contracts. This conversion would facilitate the automated implementation of business processes on a blockchain-based platform [29]. An alternative methodology entails the transformation of business process models, specifically BPMN models, into state charts tailored to the block typology of the blockchain. This enables the implementation of collaborative processes by utilizing auxiliary tools founded on blockchain technology (BCT) [30]. Utilizing these modeling approaches is vital for capitalizing on the advantages

of blockchain technology in BPM and has been the subject of substantial research and development endeavors.

The prospective advantages of integrating blockchain and BPM via modeling approaches include increased security, automation of business processes, and trust. Organizations can achieve operational streamlining and security by converting BPMN models into blockchain smart contracts, which subsequently automate the execution of intricate business processes [29]. This transformation eliminates the necessity for intermediaries. Furthermore, utilizing blockchain-adaptable state charts to represent business process models facilitates the implementation of collaborative procedures by applying BCT-based tools, thereby augmenting the effectiveness and dependability of workflows across organizations [30]. These modeling approaches facilitate the extensive implementation of blockchain technology in BPM and are currently the focus of ongoing research to improve their efficacy and practicality.

Even with its prospective advantages, the amalgamation of blockchain and BPM via modeling methodologies also engenders many obstacles and factors to be considered. A significant obstacle is the intricacy of synchronizing current BPMN models with the demands of blockchain technology. This may necessitate reengineering business processes to optimize the potential of blockchain [31]. Furthermore, preserving privacy and confidentiality for sensitive business process data stored on a public blockchain continues to be a substantial issue, necessitating the creation of appropriate governance frameworks and privacy-preserving techniques [32]. To fully leverage blockchain technology in BPM, it is critical to confront these obstacles; doing so necessitates a multidisciplinary approach that integrates knowledge and skills in BPM, blockchain technology, and information security.

### *2.1. Traditional BPM Modeling*

Traditional approaches to Business Process Modeling (BPM), illustrated by widely used standardized notations such as BPMN and UML, have been instrumental in streamlining and optimizing sequential and linear business processes within centralized frameworks [33,34]. These methods are particularly effective at representing conventional operations and organizational frameworks in which a solitary authority supervises and carries out procedures. The main characteristics and applications of conventional BPM modeling techniques (BPMN, UML, ERD, DFD) in representing business processes, system architecture, database design, and data flow within systems are outlined in Table 1.

**Table 1.** Comparison of traditional BPM modeling techniques.

| Modeling Technique | Key Characteristics | Primary Components | Application |
| --- | --- | --- | --- |
| BPMN (Business Process Model and Notation) | Standardized visual notation for business processes. | - Flow Objects (Activities, Events, Gateways) | Sequential process modeling, clear representation of workflow. |
| UML (Unified Modeling Language) | General-purpose modeling language with broader applications. | - Use Case Diagrams<br>- Activity Diagrams<br>- Sequence Diagrams | System architecture and design are not exclusive to business processes. |
| ERD (Entity-Relationship Diagrams) | Focus on database design and representation of entities. | - Entities<br>- Relationships<br>- Attributes | Database design, understanding relationships between entities. |
| DFD (Data Flow Diagrams) | Visualizes the flow of data within a system or process. | - Processes<br>- Data Stores<br>- Data Flows | Illustrating information flow, system components, and data movement. |

However, when confronted with blockchain technology's decentralized and distributed characteristics, these conventional models need help [35]. A substantial obstacle arises in incorporating critical components unique to blockchain technology, including decentralized consensus mechanisms, smart contract complexities, and asset tokenization [36,37]. The conventional BPM methodology, originally developed to accommodate centralized settings with presumptions of trust, needs to adequately capture the trustless and tamper-resistant characteristics vital to blockchain transactions.

Despite their effectiveness in traditional settings, these models encounter limitations when applied to blockchain scenarios. These challenges include the following:

- Decentralized Consensus: Traditional models need help representing the decentralized consensus mechanisms fundamental to blockchain, where multiple parties collectively validate transactions.
- Smart Contracts: The intricate logic of smart contracts, integral to blockchain processes, is not easily accommodated within traditional BPM notations.
- Tokenization: Representing the tokenization of assets and their decentralized management poses a challenge within the traditional BPM framework.

Traditional BPM models are intended for centralized, trust-based environments. The trustless and tamper-resistant attributes of blockchain transactions, which are intrinsic to the technology's value proposition, might need to be sufficiently captured.

### *2.2. Blockchain-Oriented Modeling*

Blockchain-oriented modeling signifies a fundamental transformation in the conventional realm of BPM. This methodology seamlessly incorporates blockchain technology's complexities and distinctive attributes into the modeling procedure. The primary emphasis is on integrating blockchain technology's trust-based, tamper-resistant, and decentralized characteristics into operational procedures [9].

Blockchain-oriented modeling transcends the conventional linear and centralized structures observed in BPM through the development of process models [38]. Conversely, it adopts the distributed and decentralized characteristics inherent in blockchain networks. This encompasses the depiction of nodes, smart contracts, and the cryptographic mechanisms that support the ledger's integrity and immutability [39].

When employing this modeling approach, several distinctive factors become prominent. Visual representations are required to illustrate the function of decentralized consensus mechanisms in transaction validation, such as proof-of-work or proof-of-stake. Smart contracts, characterized by their autonomous execution on the blockchain, are seamlessly integrated into the models, thereby exhibiting their triggers and outcomes. Furthermore, explicit representation is necessary to communicate the administration and flow of digital assets within the business processes, as symbolization of assets is a defining characteristic of numerous blockchain applications [40].

Although blockchain-oriented modeling has the potential to improve efficiency, security, and transparency, it is full of obstacles. It can be challenging to convey to stakeholders acclimated to centralized models the complexities of decentralized systems. The delicate task of reconciling the necessity for transparency with the criticality of data privacy represents an additional obstacle that demands thoughtful deliberation. Notwithstanding these obstacles, the prospects offered by modeling with a blockchain focus are substantial, granting enterprises the capability to optimize operations within an environment devoid of trust [41]. The iterative interaction between BPM processes and critical blockchain attributes is illustrated in Figure 1. Data flow and interaction, data validation, security, audit trail, reporting, and analytics are some of the phases of the BPM process. Key blockchain elements, such as setup, smart contracts, consensus processes, and asset tokenization, are smoothly integrated concurrently. The closed-loop structure illustrates how data move through interactions, go through blockchain validation and consensus, add to a secure audit trail, and are finally used for reporting and analytics. This structure represents the iterative nature of the BPM process [42,43].

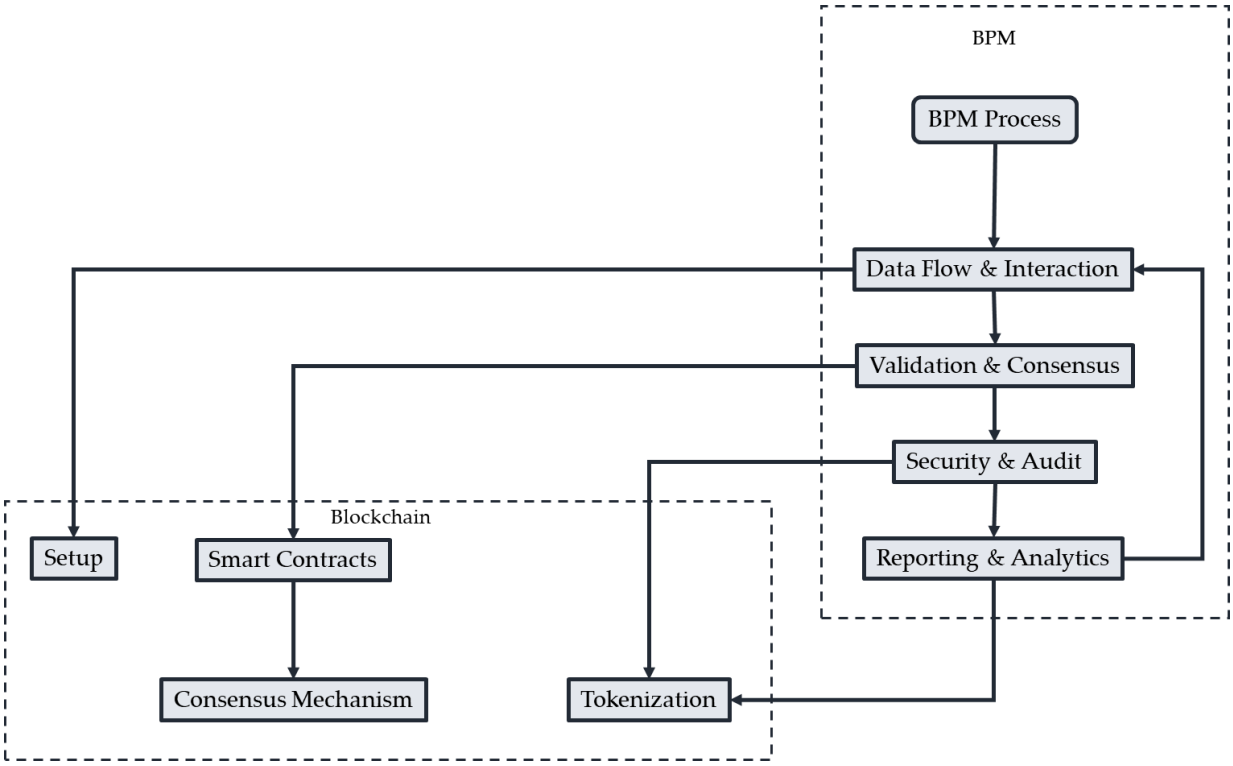


**Figure 1.** BPM process with blockchain integration.

### *2.3. Hybrid Approaches*

Hybrid models aim to merge the organization and precision provided by conventional BPM with the decentralized and tamper-resistant characteristics that are distinctive to the blockchain. Hybrid methodologies, which integrate blockchain components with conventional BPM, present an adaptable resolution to contemporary business requirements [19,44]. One significant benefit is their capacity to effectively integrate the streamlined processes of conventional BPM with the decentralized, transparent, and tamper-resistant attributes of blockchain technology. This framework offers organizations a comprehensive and inclusive approach to modeling by ensuring adaptability across various operational structures.

In addition, through the incorporation of blockchain's fundamental characteristics, hybrid models bolster transparency and confidence. These systems empower organizations to utilize blockchain-specific functionalities, including smart contracts and decentralized consensus mechanisms, while maintaining the transparency offered by conventional BPM. Moreover, the tamper-resistant characteristic of blockchain enhances the security of hybrid approaches by minimizing susceptibility to data manipulation and illicit modifications. By leveraging this enhanced security and adaptability, organizations can fortify their operational procedures against the ever-changing technological environment.

Conversely, implementing hybrid methodologies that effectively merge conventional BPM with blockchain-specific components is a complex yet auspicious undertaking. One significant obstacle is the assurance of compatibility and seamless integration between blockchain technology and conventional BPM tools. These domains frequently use disparate technical frameworks and data structures, necessitating careful strategizing to avert complications throughout the integration process. Thorough deliberation is required to ensure a seamless exchange of data and operations while centralized and decentralized components coexist. Concurrently, implementing blockchain-specific components adds intricacy, requiring comprehensive user instruction and training. In the face of heightened complexity, it is vital to secure user support to facilitate stakeholders' understanding and navigation of hybrid models.

Furthermore, hybrid methodologies are confronted with the challenge of guaranteeing the integrity and protection of data. The decentralized and tamper-resistant characteristics of blockchain technology give rise to novel concerns, including protecting data integrity throughout transitions and establishing secure communication conduits between conventional and blockchain systems. An additional obstacle lies in the need for hybrid models to accommodate a wide range of business processes while maintaining adherence to standardized practices to ensure interoperability. Lifecycle management and maintenance present continuous obstacles, necessitating organizations to establish resilient procedures to update models, tackle emergent challenges, and guarantee that modifications do not impede the overall efficiency of processes. Addressing these obstacles necessitates the cooperation of IT and business stakeholders, and continuous research and development should prioritize the establishment of protocols, optimal methodologies, and instruments that optimize integration, bolster user acceptance, and guarantee the secure and uniform implementation of business operations at the intersection of blockchain and BPM.

As Section 3 of the literature review methodology outlines, these hybrid models will be evaluated according to criteria specific to their characteristics. The assessment will provide insights into their flexibility, lucidity, and overall efficacy within the complex convergence of blockchain and BPM.

## 3. Literature Review Methodology

For a thorough assessment of the various modeling approaches that intersect with blockchain technology and BPM, it is critical to have a robust methodology. The framework above integrates fundamental criteria to evaluate the models' adaptability, lucidity, and integration capabilities. The methodology consists of a methodical evaluation of particular modeling approaches, establishing a structured comparison foundation.

The review conducted in this study, informed by a comprehensive framework and adhering to a rigorous methodology, incorporates modeling approaches, criteria for selection, and metrics for evaluation based on data retrieved from reputable databases such as Scopus, ScienceDirect, and Google Scholar as of 5 December 2023.

### *3.1. Methodology*

#### 3.1.1. Search Keywords

For the search process in the literature review, the main search keywords in the titles of the papers include:

- Blockchain and BPM;
- Business Process Modeling with Blockchain;
- Blockchain and Business Process Management;
- Smart Contracts and Business Process;
- Decentralized and Business Process.

The selection of these keywords was deliberate to encompass a wide array of scholarly works that pertain to the amalgamation of blockchain technology and BPM. This guarantees that the review will encompass diverse facets of modeling methodologies and their efficacy in tackling the distinctive characteristics of blockchain technology.

#### 3.1.2. Inclusion Criteria

The selected literature focused on modeling approaches integrating blockchain technology with business processes. Inclusion criteria encompassed studies that discussed traditional BPM modeling, blockchain-oriented modeling, and hybrid models.

#### 3.1.3. Exclusion Criteria

Literature that did not specifically address blockchain integration with BPM or provide insights into modeling approaches was excluded from the analysis. Additionally, studies lacking empirical evidence or not meeting academic rigor were excluded.

### *3.2. Selection Process*

#### 3.2.1. Initial Screening

The initial screening assessed the literature's relevance based on titles and abstracts. This step aimed to filter out irrelevant or tangentially related articles.

#### 3.2.2. Full-Text Review

Articles passing the initial screening underwent a thorough full-text review. This phase involved a deeper examination of the content to ensure alignment with the study's focus on modeling approaches.

#### 3.2.3. Data Extraction

Relevant data, including modeling techniques, key findings, and any comparative insights, were extracted from the selected articles. This information formed the basis for the subsequent literature analysis.

#### 3.2.4. Selected Papers

After eliminating 22 duplicates from an initial sample of 78 papers, the final set comprised 56 unique papers. A comprehensive examination was conducted using predetermined standards to determine the significance of 45 papers about integrating blockchain technology and BPM (Figure 2). By employing this methodology, the literature review is conducted methodically and rigorously, laying the groundwork for a robust evaluation of the identified modeling approaches in integrating blockchain and BPM.

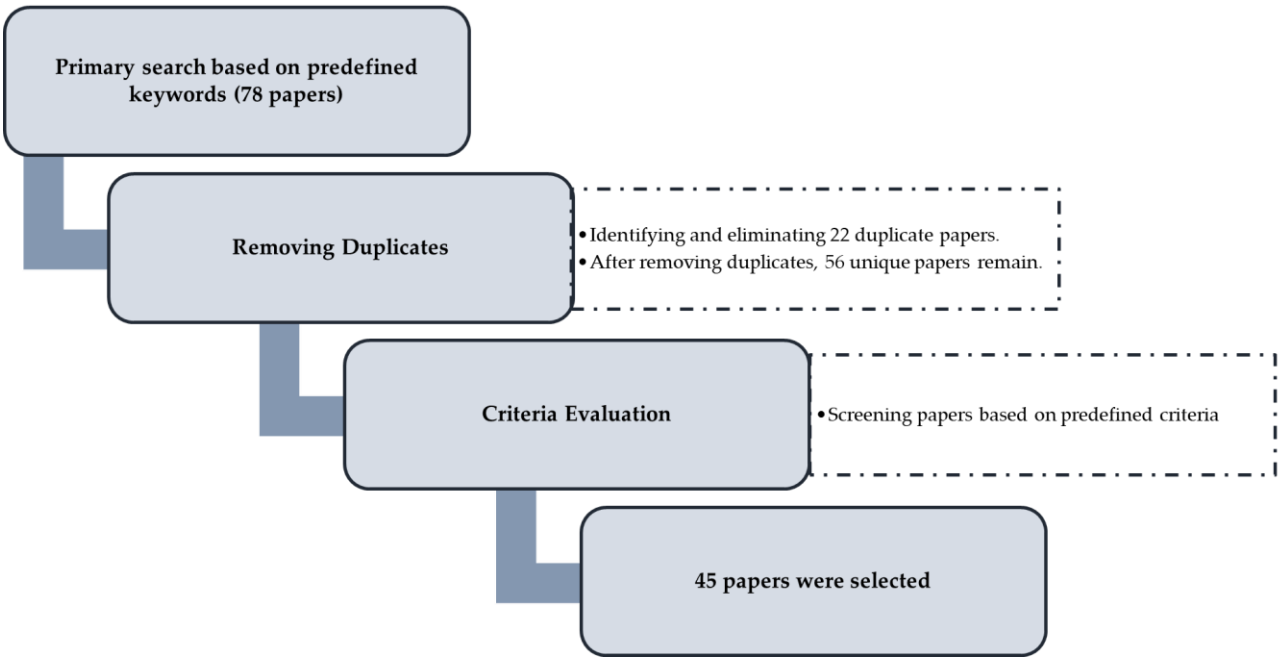


**Figure 2.** Paper selection process.

The following are the published papers about this investigation throughout the years (Figure 3): Three papers were published in 2023, five in 2022, and eleven in 2021—the year with the greatest representation. There were seven papers in 2020 and six in 2019. Two papers were published in the early phases of blockchain technology in 2008. It is worth noting that no papers were documented for 2013, 2012, 2011, and 2010. Two publications were published in 2009, whereas none were produced from 2007 to 2003. The analysis above underscores the progressive fascination surrounding the convergence of blockchain technology and BPM. Blockchain's importance was initially recognized in 2008.

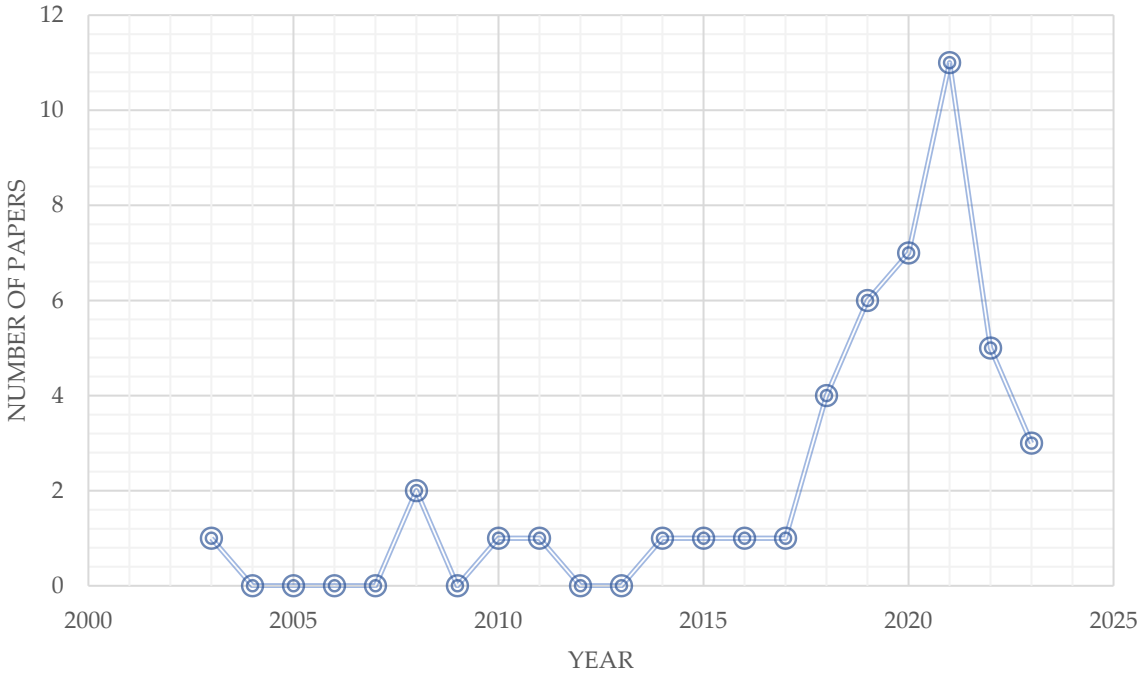


**Figure 3.** The trend of publishing papers over 20 years.

## 4. Strengths and Weaknesses of Modeling Approaches

Organizations investigating the amalgamation of blockchain technology and BPM confront an assortment of modeling methodologies, each endowed with unique advantages and disadvantages. Comprehending these characteristics is essential for exercising discernment when integrating procedures with blockchain technology's functionalities.

### *4.1. Traditional BPM Models*

#### 4.1.1. Strengths

Recent studies have underscored the merits of traditional BPM models for business processes. These models demonstrate exceptional performance in promoting process efficiency and repeatability, as exemplified by the research conducted by Lyridis et al. [25] on the midstream LNG supply chain. The study highlights the ability of BPM to detect and resolve inefficiencies associated with the substantial number of transactions among stakeholders, thereby facilitating the optimization of processes. The enhanced visibility results in improved operational performance and provides stakeholders with a valuable instrument to quantify the potential ramifications of blockchain technology on their activities, encompassing advantages like reduced costs and time.

In addition, the research underscores BPM's capability to offer a comprehensive visual representation of business processes indirectly. Milani et al. [45] examine the comparative analysis of CMMN and BPMN in modeling blockchain-oriented processes. Their research further supports the claim that BPM provides a comprehensive perspective on supply chain operations. Despite these merits, difficulties emerge in fulfilling blockchain-specific obligations, such as tokenization. This implies continuous investigation and adjustment of BPM models are required to guarantee a smooth integration with developing blockchain technology. This would establish a symbiotic relationship between BPM's established strengths and blockchain's emergent functionalities. Key aspects of BPM modeling approaches from numerous articles are summarized in Table 2.

**Table 2.** Traditional BPM modeling approaches.

| Study | BPM Modeling Type | Industry/Application | Findings/Contributions |
| --- | --- | --- | --- |
| [25] | BPM for Impact Assessment of Blockchain in LNG Supply Chain | Midstream LNG Supply Chain Management | Framework for assessing blockchain impact, identifying inefficiencies. |
| [45] | BPMN vs. CMMN | General Blockchain Applications | Neither BPMN nor CMMN fully represents blockchain patterns. |
| [46] | Decentralized Data Management System | Collaborative Distributed Environment | ProvHL is for reliable provenance metadata management, a new blockchain-based rights delegation method. |
| [47] | Transformation of BPMN to Smart Contracts | Hyperledger Fabric | Importance of transforming BPMN models for Hyperledger Fabric. |
| [48] | BPM Model for Supply Chain in Blockchain and IoT System | Cross-organizational Luxury Supply Chain | The proposed BPM model for supply chain simulation shows direct usability. |
| [49] | Model-Driven Architecture for Blockchain | General Blockchain Applications | Proposed MDA method for defining blockchain structure. |
| [50] | Plural Method | Business Process Modeling | Applied the Plural method to small software organizations, discussing its utility and limitations. |

#### 4.1.2. Limitations in Addressing Blockchain-Specific Requirements

Conventional BPM frameworks, most notably the Business Process Model and Notation (BPMN), demonstrate specific merits, including the augmentation of process efficiency and repeatability. However, significant limitations become apparent when confronted with the specific requirements of blockchain applications. Milani et al.'s [45] comparative analysis draws attention to the inadequacies of BPMN in representing tokenization, a crucial component of blockchain-oriented processes. Tokenization is a process wherein digital tokens represent assets on a blockchain; however, BPMN needs to offer adequate support for this particular blockchain pattern. Additionally, the study above highlights the limitation of BPMN in differentiating between on-chain and off-chain data storage and executed operations, which compromises its ability to depict the complexities of blockchain technology accurately.

Demichev et al. [46] support these constraints by stating that conventional BPM models might encounter challenges when attempting to account for the intricacies inherent in decentralized environments comprehensively. Integrating blockchain technology, smart contracts, and provenance metadata presents an additional level of complexity that conventional BPM methodologies may need to tackle sufficiently. Furthermore, Hriberšek's [47] research suggests that BPMN might be deficient in the adaptability required to seamlessly convert into smart contracts, which are indispensable for many blockchain-based applications. The proposal for a Model-Driven Architecture-based method by Jurgelaitis et al. reflects the need for a more general and flexible language to describe blockchain-based systems, implying that current BPM models might be inadequate when confronted with the intricacies of blockchain implementations.

Although traditional BPM models provide advantages in enhancing the consistency and effectiveness of processes, they need help with catering to the distinct demands of blockchain applications. The issues above, which include difficulties in tokenization representation and the inability to differentiate between on-chain and off-chain data, highlight the necessity for additional investigation and modification of BPM models to incorporate seamlessly with the intricacies of blockchain technology. These limitations need to be recognized by practitioners and researchers to guarantee the successful integration and implementation of BPM in processes oriented toward blockchain technology.

### *4.2. Blockchain-Oriented Models*

#### 4.2.1. Advantages of Decentralized and Tamper-Resistant Processes

Blockchain technology provides notable benefits regarding decentralized and tamper-resistant operations within business models, encompassing improved transparency, security, and efficiency. Table 3 categorizes articles concerning blockchain-oriented models.

**Table 3.** Classification of blockchain-oriented models in reviewed articles.

| Study | BPM Aspect | Blockchain Use Case | Methodology |
|---|---|---|---|
| [43] | BPM Patterns | Credit and Claim Requests | Design Science Research |
| [51] | Process Automation | Business Processes | Comparative Analysis |
| [52] | BPM Patterns | Loan Application | Design Science Research |
| [53] | Smart Contracts | Marketplace Service | Methods for Designing |
| [54] | Tokenization | Business Process Models | Proposed Approach |
| [55] | Model-Driven Engineering | Cross-Organizational Processes | Proposed MDE Approach |
| [56] | BPM in Health Care | COVID-19 Cases | Proposed BBPM System |
| [57] | Trust Management | Collaborative Business Processes | Methodology and Tool |
| [58] | Model Checking | Solidity Smart Contracts | Formal Approach |
| [59] | Transaction Model | Business Process Modeling | Proposed Transaction Model |
| [60] | Smart Contracts for E-Government | E-Government Services | Model-Based Proposal |
| [61] | Execution of Blockchain-Aware Processes | Blockchain-Based Interactions | Proposed Modeling Extension |
| [62] | Smart Contracts in Corporate Processes | Corporate Business Processes | Proposed Prototype Tool |
| [63] | Blockchain Hashes for Business Processes | Blockchain-Based Smart Contracts | Critique of BSCs |
| [64] | CEP for BP Monitoring | CEP Techniques | Proposed dBPM Mechanism |
| [65] | Blockchain Evolution | Integration with IoT | Proposed Blockchain Lifecycle |
| [66] | Decentralized Process Modeling | Enterprise Models | Introduced Approach |
| [67] | BPM System on Ethereum | BPM System Overview | BPMN-To-Solidity Compiler |
| [68] | Role-Based Modeling | Collaborative Process Modeling | Proposed ROADMap Method |

The study by Molnár et al. [43] highlights how the decentralized characteristics of blockchain technology improve the efficiency of financial processes, specifically credit and claim requests. The study emphasizes blockchain technology's capacity to thwart inaccurate data utilization, thereby safeguarding sensitive information and enabling the secure exchange of data in financial transactions.

Furthermore, the technical implications of integrating smart contracts for business process automation are examined in the research article by Chikov et al. [51]. The paper highlights the significance of blockchain technology in enhancing internal operational efficiency and productivity, reducing transaction costs, and ensuring cybersecurity and dependability. This exemplifies the benefits that decentralized automation can provide in terms of safeguarding the effectiveness and integrity of business processes.

The benefits of blockchain-based smart contracts in service-oriented business processes are illustrated in the study by Parjuangan et al. [53]. It emphasizes the implementation of automated procedures and the generation of immutable ledgers of transactions on the blockchain. This exemplifies the decentralized characteristics of blockchain technology, which guarantees integrity and openness in environments focused on services. These papers collectively demonstrate how blockchain's decentralized and tamper-resistant characteristics enhance the effectiveness, security, and transparency of various business operations across sectors.

#### 4.2.2. Challenges in User Comprehension and Adoption

Incorporating blockchain technology into operational procedures presents benefits and obstacles, specifically regarding user understanding and acceptance. Comprehending and efficiently executing models focused on blockchain presents substantial challenges that need to be confronted to achieve successful integration. Numerous research papers provide valuable insights and cast light on these challenges.

The technical intricacies of smart contract implementation for business process automation are examined in depth by Chikov et al. [51], who emphasize the criticality of cybersecurity and high reliability throughout contract execution. The research acknowl-

edges that it can take time to fully grasp the complexities of smart contracts and how to integrate them into pre-existing business operations. This necessitates a strong comprehension from both the business and IT standpoints.

In the same way, Garfatta et al. [58] center their research on the formal validation of Solidity smart contracts implemented within organizational procedures. The paper underscores smart contracts' vulnerability, which also presents a formal method for converting them into a Hierarchical Colored Petri net. By employing this methodology, one not only identifies weaknesses but also tackles the obstacle of guaranteeing the accuracy of smart contracts within the framework of business operations.

Yue [59] proposes a blockchain-inspired, multi-layered transaction model for business process modeling. Informed by blockchain technology, this model incorporates formalisms and properties, including statefulness, privacy, and accountability. This perspective presents a unique viewpoint but highlights the difficulty of modifying conventional transaction principles to align with the decentralized and transparent characteristics of blockchain-oriented business processes.

Gómez et al. [60] investigate the design and development processes of smart contracts to facilitate e-Government services. It is widely recognized that incorporating blockchain technology and smart contracts into public services is a challenging endeavor that necessitates an exhaustive comprehension of administrative and technological facets. This underscores the difficulty of promoting user understanding and implementation in administrative and governmental environments. As demonstrated by López-Pintado et al. [67], the Caterpillar system is a BPM system that utilizes blockchain technology. Although the system utilizes the Ethereum blockchain to facilitate transparent process execution, user adoption and comprehension remain significant obstacles to maximizing the potential of such systems.

In summary, user adoption and comprehension of blockchain-oriented models are hindered by many obstacles, including technical intricacies, formal verification prerequisites, and the necessity for an all-encompassing comprehension of blockchain technology and business procedures. It is crucial to tackle these obstacles to facilitate effective integration and maximize blockchain technology's advantages to operational procedures.

### *4.3. Hybrid Models*

#### 4.3.1. Synergies Achieved by Combining Traditional and Blockchain-Oriented Approaches

The investigation of hybrid models, which merge conventional BPM (BPM) methodologies with blockchain-centric approaches, has been the subject of numerous scholarly articles illuminating the benefits of this seamless integration. A paper by Jesse [69] is notable for its implementation of smart contracts and blockchain technology to automate business procedures. A central theme is the elimination of intermediaries, which exemplifies the collaborative potential of blockchain technology and traditional BPM. The decentralized and tamper-resistant characteristics of blockchain enable the execution of contractual processes seamlessly, thus showcasing the synergy between the two. This novel methodology enhances the efficiency of contract automation and data exchange, representing a substantial advancement in the convergence of these two fields.

Another noteworthy addition to the discourse surrounding hybrid models is the article by Kopp et al. [70]. The authors suggest implementing blockchain technology in a decentralized repository for business process models. The symbiosis above is evident in the repository's utilization of the distributed ledger functionalities of blockchain technology, which furnishes a stable and secure means of storing and retrieving collections of business process models. The repository's decentralized architecture improves security, availability, and integrity, demonstrating how blockchain-oriented structures can be integrated to enhance conventional BPM practices [70].

A paper by Loukil et al. [71] makes an additional contribution by introducing CoBuP, a blockchain-based architecture for decentralized collaborative business process execution. The interpreter of BPMN process models demonstrates symbiosis by facilitating the

execution, monitoring, and instantiation of process instances. The ability to dynamically update the adaptation of a process at runtime and deploy a generic smart contract once exemplifies the decentralized execution capabilities and flexibility that can be obtained by integrating traditional BPMN with blockchain. The potential for collaborative and adaptable business processes is underscored in this study, which addresses the inflexibility issue frequently associated with blockchain-based systems. These papers highlight the potential for enhanced productivity and novel ideas that can arise from the seamless integration of conventional BPM methods and blockchain-focused strategies. Table 4 provides a comprehensive overview of sixteen articles that examine the convergence of blockchain technology and BPM. The articles are classified according to their synergies, utilization of smart contracts, blockchain applications, and overall integration.

**Table 4.** Overview of articles on hybrid models integrating BPM and blockchain.

| Study | Synergies | Use of Smart Contracts | Blockchain Applications | Integration of BPM and Blockchain |
|---|---|---|---|---|
| [69] | ✓(Automation, Data Sharing) | ✓ | Financial Processes | Innovative Automation |
| [70] | ✓(Security, Stability) | - | Business Process Repository | Secure BPM Repository |
| [71] | ✓(Flexibility, Collaboration) | ✓ | Inter-organizational Processes | Collaborative Execution |
| [72] | - | ✓ | Cross-organizational Processes | Validation of Smart Contracts |
| [73] | ✓(Artifact-centric Processes, Smart Contracts) | ✓ | Inter-organizational Processes | Ontological Analysis |
| [74] | ✓(Multi-party Relationship, Trust) | ✓ | Multi-party Systems | Distributed Business Process System |
| [75] | - | - | Inter-organizational Processes | Temporal Constraints in Design |
| [76] | ✓(Simulation, Data-driven Analysis) | ✓ | Inter-organizational Processes | Simulation-based Design |
| [28] | ✓(Big Data Integration) | - | Economic Systems | Blockchain-Big Data Synergy |
| [77] | ✓(Traceability, Control) | ✓ | Supply Chain | Decentralized Enforcement |
| [78] | ✓(MDE, Asset Management) | ✓ | Asset Management | Model-driven Engineering |
| [79] | - | - | Decentralized Execution | BPMN Extensions |
| [80] | - | - | Inter-organizational Automation | Decentralized Automation |
| [81] | - | ✓ | Compensation Processes | Agent-based Compensation |
| [82] | - | - | Event-driven Processes | Decentralized Governance |
| [83] | - | - | Cross-enterprise Collaboration | ICT Architecture for BPM |
| [84] | ✓(Workflow Technology and Peer-To-Peer Computing) | - | Decentralized Workflow | Decentralized BPM |

#### 4.3.2. Potential Drawbacks and Complexities Introduced by Hybridization

Hybrid models, which integrate blockchain-oriented methodologies with conventional BPM approaches, offer a potentially effective solution to the distinct obstacles presented by decentralized and tamper-resistant business processes. Nevertheless, this amalgamation of models is full of possible disadvantages and intricacies. By thoroughly examining the perspectives in numerous academic articles, one can acquire a more sophisticated comprehension of the complexities of hybridization.

A significant obstacle is the smooth amalgamation of conventional BPM and blockchain frameworks, as emphasized by numerous studies. Van Wingerde and Weigand [73] examine the potential complexities and difficulties of integrating smart contracts with artifact-centric processes. As a result of the ontological analysis, the conceptual relationship between business process artifacts and smart contracts needs to be clarified further, underscoring the difficulty of managing inter-organizational processes.

The paper by Alves et al. [74] highlights the difficulties associated with ensuring strict adherence to business rules and reliability in a multi-party environment. Incorporating blockchain technology into a BPM System (BPMS) presents intricacies about establishing a secure registry resistant to tampering, implementing smart contracts for self-execution, and preserving a trustworthy environment for all participants.

Franceschetti and Eder's [75] article examines the potential complexities that temporal constraints may introduce into decentralized business processes. The delicate challenge of balancing expressiveness and minimal coupling in formulating temporal requirements highlights the complexities of integrating time-sensitive components into hybrid models.

To surmount these obstacles, organizations and professionals should deliberate on approaches to reduce intricacies while integrating conventional and blockchain-centric frameworks. In light of the findings presented in the studies above, it is critical to develop standards for harmonizing the various components of hybrid models. This entails resolving

concerns about standardization, interoperability, and the possibility of conflicts emerging throughout the integration procedure.

In summary, although hybrid models present a potent remedy for capitalizing on the advantages of conventional BPM and blockchain-centric methodologies, their integration may introduce certain disadvantages and complexities that necessitate meticulous examination. By comprehending these obstacles, organizations can formulate well-informed approaches to cultivate a prosperous synergy among diverse modeling paradigms within the perpetually evolving domain of blockchain and BPM integration.

## 5. Future Trends and Recommendations

Blockchain and BPM developments of the future are anticipated to have a substantial effect on a variety of industries. The research firm Gartner projects that by 2030, the value added by blockchain technology to business operations will surpass USD 3.1 trillion, and by 2026, it will have increased to over USD 360 billion [85,86]. These trends suggest that blockchain technology will remain increasingly significant in business. Regarding BPM, it has developed into an established field characterized by tools, principles, and methodologies that all strive to enhance business processes [87]. Significant advancements have been achieved in BPM, process modeling, and syntactic verification of intricate business process models [88]. BPM continues to be extensively implemented in practice for administering business processes and attaining organizational objectives [89]; its evolution is continuous.

### *5.1. Recommendations for Businesses and Practitioners*

#### 5.1.1. Choosing the Most Suitable Modeling Approach

Selecting an appropriate modeling approach for integrating blockchain technology with BPM is a critical determination that requires an exhaustive assessment of numerous elements. Before anything else, it is critical to have a comprehensive comprehension of business requirements, which will assist in identifying process-specific elements that blockchain integration intends to improve. The chosen modeling methodology should be able to effectively manage blockchain-specific components, including decentralized consensus, smart contracts, tokenization, and secure data administration. The modeling approach must also be adaptable to change, guaranteeing that it can accommodate forthcoming advancements in blockchain technology without necessitating a comprehensive reevaluation.

Furthermore, the level of user adoption and comprehension has a substantial impact on the process of making decisions. The selected modeling methodology should provide lucid and user-friendly depictions that promote efficient correspondence among technical and non-technical parties involved. Prioritizing compatibility with pre-existing IT infrastructure, scalability, and performance guarantees a smooth integration with current systems while providing for potential future expansion. In addition, it is crucial to consider community support, cost implications, and regulatory conformance when selecting a method. This ensures that the chosen approach complies with industry norms, safeguards privacy and security, and is supported by an active community for continuous assistance. Pilot tests are a valuable tool for organizations to evaluate the feasibility and efficacy of the selected modeling approach before its extensive implementation. This enables the identification of potential obstacles and facilitates the implementation of adjustments essential for a successful outcome.

#### 5.1.2. Adapting to Evolving Technologies and Methodologies

The effective incorporation of blockchain into BPM necessitates the ability to adjust to dynamic technologies and methodologies. The chosen modeling methodology ought to possess scalability and adaptability, enabling the smooth integration of novel attributes and blockchain technology advancements while preserving the integrity of existing models [90]. Adherence to modern BPM methodologies is critical, which requires stakeholders to make

a continuous investment in training and skill enhancement to utilize the most recent developments in process management effectively

Developing an organizational culture that promotes innovation is of equal importance. This requires fostering collaboration between the business and IT teams to refine the modeling approach and exchange insights continuously. Consistent assessments of industry standards and best practices ensure the organization remains at the vanguard of technological developments. Partnerships with technology providers and industry frontrunners provide additional access to state-of-the-art tools and insights, which aid in the continuous improvement and adjustment of the modeling methodology to align with the changing demands of the organization.

#### 5.1.3. Cost-Effectiveness and Efficiency

Adopting blockchain technology can aid in preventing fraud, enhancing organizational functions and procedures, and reducing blunders in business transactions [91]. However, for some organizations, the cost of blockchain implementation may be prohibitive. Businesses can reduce the cost of blockchain implementation by monetizing the process, regulating maintenance expenses, and collaborating efficiently.

A study conducted by Agi et al. [92] reveals that blockchain technology's relative advantage, complexity, and cost have substantial implications for its implementation within the supply chain. When employing this technology, businesses should consider the cost-effectiveness of blockchain implementation. The utilization of a cost-effectiveness model can assist stakeholders in evaluating the execution of blockchain technology and ascertaining the specific cost structures that will be borne by each stakeholder in the network [93].

Moreover, blockchain technology can enhance customer experience in credit and claim requests while decreasing administrative expenses [43]. By automating tasks, blockchain is a scalable technology that can facilitate business processes, promote innovation, and support large volumes of transactions. Therefore, when evaluating the cost-effectiveness of this technology, businesses and practitioners should consider the potential benefits of blockchain adoption, including increased traceability, security, and transparency [91].

## 6. Conclusions

A literature review of modeling approaches at the intersection of blockchain technology and BPM reveals a dynamic landscape where traditional and blockchain-oriented models vie for prominence. The investigation into these methodologies and the rise of hybrid frameworks highlight the dynamic characteristics of technology incorporation within organizational procedures.

The analysis of conventional BPM modeling methods has revealed their efficacy in supporting established procedures but exposed their shortcomings in accommodating blockchain applications' decentralized and tamper-resistant characteristics. On the other hand, models focused on blockchain demonstrate competence in managing the distinctive characteristics of distributed ledgers; however, they need help in user understanding and acceptance. The convergence of conventional BPM and blockchain-centric methodologies exemplifies synergies that capitalize on the respective merits of both frameworks. Although this hybridization offers prospects for novel solutions, it also introduces intricacies that necessitate meticulous deliberation.

As we contemplate the future, emergent trends indicate that the integration of blockchain and BPM will continue to develop. Progress in modeling methodologies is anticipated within the industry, propelled by the continuous evolution of blockchain technologies and the established status of BPM approaches. When maneuvering through this dynamic environment, it is advisable for organizations and professionals to thoroughly assess their distinct requirements and the characteristics of their procedures. The selection of an appropriate modeling approach, be it conventional, blockchain-centric, or a hybrid model,

ought to be a calculated choice based on the objectives and technological capacities of the organization.

Proactive adaptation is imperative in light of the exponential rate of technological progress. Organizations are highly encouraged to remain updated on emergent technologies and methodologies to cultivate a culture that is receptive to innovation and change. The potential of the synergy between blockchain technology and BPM modeling approaches to reshape the conceptualization and execution of business processes is enormous. This synergy represents a strategic alignment rather than a simple convergence of technologies; it has the potential to foster increased transparency, efficiency, and trust within a business environment that is becoming more interconnected and digital.

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