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MODEL OF INTEGRATED ASSESSMENT LAYER FOR IMPLEMENTATION READINESS OF BLOCKCHAIN-BASED TRACEABILITY SYSTEM

MODEL LAPISAN PENILAIAN TERINTEGRASI UNTUK KESIAPTERAPAN IMPLEMENTASI SISTEM INFORMASI KETERTELUSURAN BERBASIS BLOCKCHAIN

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ABSTRAK

Di tengah perkembangan teknologi blockchain di berbagai sektor, penelitian ini mengusulkan Model Penilaian Terintegrasi baru untuk mengevaluasi kesiapan penerapan sistem berbasis blockchain. Penelitian ini dilakukan secara bertahap dengan menggunakan pendekatan sistem evaluasi proyek yang dimodifikasi, yang mencakup serangkaian proses seperti tinjauan literatur sistematis, observasi dan wawancara, serta penilaian studi kasus menggunakan BDD dan SEM-PLS. Tinjauan literatur yang komprehensif mengungkapkan beberapa area penting untuk menilai kesiapan adopsi teknologi blockchain: kematangan teknis, kesesuaian domain, lanskap peraturan, dan dinamika pemangku kepentingan. Berdasarkan temuan ini, model yang diusulkan disusun menjadi lima lapisan: teknologi, bisnis, data, peraturan, dan antarmuka pengguna. Sebagai tindak lanjut penelitian pengembangan analisis dan desain sistem penelusuran berbasis blockchain pada kopi Kintamani, BDD mengonfirmasi keterlibatan pemangku kepentingan. Selain itu, kesiapan pengguna untuk berubah menggunakan sistem berbasis blockchain terutama ditentukan oleh kompatibilitas teknologi (TC) berdasarkan hasil SEM-PLS dan IPMA. Kontribusi utama penelitian ini adalah terhadap adopsi blockchain dengan mengusulkan kerangka kerja yang komprehensif dan praktis – Model Penilaian Terpadu. Disarankan agar penelitian di masa depan diarahkan pada pengembangan model untuk konteks kasus yang lebih spesifik, memperluas kesesuaian untuk kerangka kerja blockchain yang baru muncul, berfokus pada wilayah tertentu, dan penelitian longitudinal dalam hal tren dan hambatan adopsi.

Kata Kunci: blockchain, kesiapan implementasi, model penilaian, rantai pasokan pertanian pangan, sistem ketertelusuran

ABSTRACT

Amid the development of blockchain technology in various sectors, this research proposes a novel Integrated Assessment Model to evaluate readiness for implementing blockchain-based systems. This research was carried out in stages using a modified project evaluation system approach, which includes a series of processes such as systematic literature review, observation and interviews, and case study assessment using BDD and SEM-PLS. A comprehensive literature review reveals several important areas for assessing blockchain technology adoption readiness: technical maturity, domain suitability, regulatory landscape, and stakeholder dynamics. Based on these findings, the proposed model is organized into five layers: technology, business, data, regulations, and user interface. As a follow-up research on the development of analysis and design of a blockchain-based traceability system in Kintamani coffee, BDD confirmed stakeholder engagement. In addition, user readiness to change using a blockchain-based system is determined primarily by technology compatibility (TC) based on SEM-PLS and IPMA results. The main contribution of this research is to blockchain adoption by proposing a comprehensive and practical framework - the Integrated Assessment Model. It is recommended that future research be directed at developing models for more specific case contexts, expanding suitability for emerging blockchain frameworks, focusing on specific regions, and longitudinal research in terms of adoption trends and barriers.

Keywords: assessment model, implementation readiness, blockchain, traceability system, agri-food supply chains

INTRODUCTION

Initially confined as the underlying technology of Bitcoin (Nakamoto, 2008), nowadays, blockchain technology has permeated diverse domains (Singh *et al*., 2021). Its inherent ability to revolutionize industries through enhanced security, transparency, and efficiency applications (Jorika and Medishetty, 2023) has led to its adoption in government processes, cybersecurity, asset management, food safety, healthcare, and fundraising (Rawat *et al*., 2020). This widespread adoption stems from its decentralized nature, mitigating single points of failure and offering solutions to data falsification

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(Tan *et al*., 2023). Despite implementation challenges (Lokshina and Lanting, 2021), ongoing research continues to unveil its transformative potential. In operations and supply chain management, blockchain strengthens product safety, curbs counterfeiting, reduces intermediaries, and enables innovative product development. Within the Agri-food industry specifically, it enhances information quality, integrity, and traceability (Marchese and Tomarchio, 2022), potentially leading to reduced costs, improved food safety, enhanced brand reputation, increased market confidence, and optimized supply chain management (Xu *et al*., 2020). Additionally, the trust fostered by blockchain strengthens stakeholder relationships, ultimately benefiting all supply chain players (Ellahi *et al*., 2023).

While blockchain technology holds immense potential to accelerate digital transformation and foster sustainable business models in the agri-food supply chain (Dal Mas et al., 2023), it remains in its early stages, demanding further research and practical solutions (Patel et al., 2023). Integrating this technology into supply chain management is still nascent often limited to theoretical explorations (Queiroz *et al*., 2019). Existing research primarily focuses on software aspects like architecture and smart contracts (Antonucci et al., 2019). In our previous research, a blockchain-based traceability system was developed in a specific case study for the Indonesian coffee agroindustry to create a more comprehensive system design. The proposed system prototype has been produced through robust requirements engineering processes involving observations, focus group discussions, and field interviews. In addition, the development process utilized a sequential system development cycle, resulting in the Digital Business Ecosystem (DBE) framework of Indonesian coffee and the functional/operational, logical, and physical design of the proposed blockchain-based coffee traceability system (Pradana *et al.*, 2020; Pradana *et al*., 2023).

Having completed multiple iterations of system development, a crucial challenge emerges: assessing the real-world implementation readiness of the blockchain-based system. This marks a new research frontier, building upon various stakeholders' efforts in the system development process. Implementation readiness extends beyond the technical considerations of the chosen blockchain technology and its development phases. Equally important are factors involving potential users and various participants within the supply chain. Recognizing these gaps, this research proposes a novel model to evaluate the implementation readiness of a blockchain-based traceability system, specifically within the agri-food sector. Further, these findings will offer valuable insights for this specific case and contribute to the broader development of such systems across diverse domains.

Research Methods

This research adopts the AGCEBDA closed-loop structure from Li and Xiong (2011) project evaluation framework to address the knowledge gap in blockchain implementation readiness for agri-food traceability systems, as depicted in Figure 1. The evaluation commences with defining the evaluation subject (A) and its evaluation objectives (G). In this paper, this phase was done with literature analysis. A comprehensive literature review based on Brendel *et al*. (2020) was conducted on the Scopus database utilizing keywords TITLE (blockchain AND implementation OR application OR adoption AND assessment). Content analysis of retrieved articles provided insights into relevant research gaps and potential solutions. Further, semi-structured interviews with blockchain experts enriched the understanding of the challenge through qualitative data (Doody and Noonan, 2013). Building upon these findings, a novel model was synthesized to assess readiness for blockchain integration within supply chains. This model resulted from the evaluation model development process (C), culminating in a structured assessment framework (E). To demonstrate its real-world applicability, the researchers employed a case study of developing a blockchain-based traceability system for the Kintamani coffee supply chain, drawing valuable insights from Harrison *et al*. (2017); and Patnaik and Pandey (2019) about case study research.

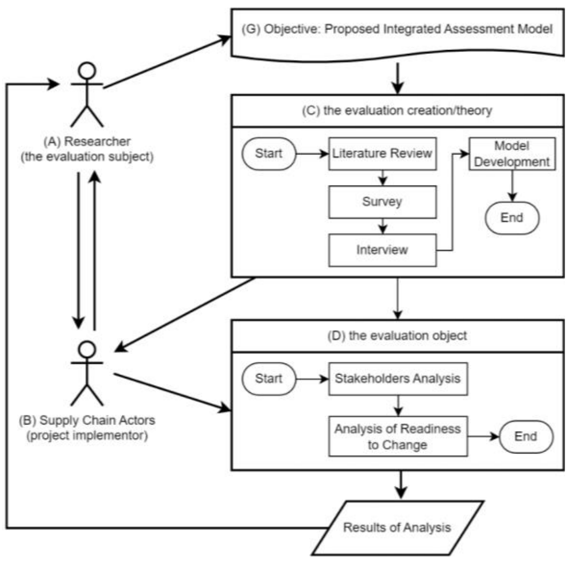

Figure 1. Research framework for blockchain-based traceability system implementation readiness, modified from project evaluation system by Li and Xiong (2011)

The evaluation model produced in the previous stage was then provided to the the supply chain actors as testers/the project implementer (B) to facilitate the evaluation of the developed system prototype (D) through designated testing procedures. At the business layer, researchers leverage a Block

Definition Diagram (BDD) within Model-Based Systems Engineering (MBSE) to map stakeholder relationships in the Kintamani coffee agro-industry supply chain (Fernandez and Hernandez, 2019). In addition, a measurement instrument based on user feedback was developed to assess the system's readiness for change at the business layer. Drawing upon Diffusion of Innovation (DOI) theory, Technology-Organizational-Environment (TOE), and Technology Acceptance Model (TAM) theories, questionnaires incorporating five exogenous variables were designed: Technology Compatibility (TC), Top Management Support (TOP), Security Concern (SC), Government Policy (GP), and Perceived Ease of Use (PEU).

The questionnaire prepared consists of four statements with a semantic scale of -3 to 3. Operational surveys were distributed to 30 key stakeholders – farmers, processors, distributors, roasters, coffee shops, and end customers. Data analysis employed Structural Equation Modeling – Partial Least Square (SEM-PLS) due to its established suitability for measuring exogenous variable influence in field information systems (Sabol *et al.*, 2023). Finally, Importance-performance Map Analysis (IPMA) provided comprehensive and representative results, achieving the research testing objectives (Ringle and Sarstedt, 2016). Finally, this multi-stage approach contributes not only to proposing a novel implementation readiness assessment model but also integrates technical evaluations and practical case studies in a series of advanced research on the development of blockchain-based traceability systems that researchers have previously developed.

RESULTS AND DISCUSSION

Research Gap of Blockchain Implementation Assessment

Implementation assessment evaluates the extent to which a program or intervention is implemented as intended (Durlak, 2014). This process includes identifying critical components, developing hypotheses, conducting analyses, and refining indicators and criteria (Kobrin *et al*., 2022). Implementation assessment can help developers identify elements that need to be improved in a system development through various methods and approaches. In this section, we present the results of a specific literature review on the implementation assessment of blockchain-based systems. Ten literatures that meet our criteria are mapped as shown in Table 1.

Following Ethereum's launch in 2014, a new "programmable blockchain" era emerged, spurred by the platform's innovative capabilities (Buterin, 2013). This breakthrough ignited global interest in harnessing this technology, with research on assessing blockchain implementation readiness taking center stage from 2019 onwards. Beyond the initial "peer-to-peer cash system" paradigm, researchers began delving into diverse application contexts, prompting vibrant debates and scrutiny on its suitability for solving real-world problems. These critical engagements surfaced scalability and privacy as fundamental challenges plaguing blockchain adoption, a theme that continues to drive numerous studies and advancements in this field (Kulkarni *et al*., 2023).

In the early stages of blockchain research, addressing technical feasibility took center stage, as evidenced by several critical studies. Gupta Gourisetti *et al.* (2019) identified cybersecurity vulnerabilities and proposed a rank-weight method for assessment, while Lu *et al.* (2019) focused on anonymity with a Bayesian network model. Jin *et al*. (2019) developed a Pythagorean fuzzy linguistic MADM model for optimal selection to address scalability as a hurdle to sustainable blockchain products. Finally, Ozdemir *et al*. (2020) aimed to establish primary criteria for assessing blockchain-based distributed applications, focusing on governance models, platforms, consensus types, cryptocurrency use, smart contracts, and tokens. These pioneering studies, emphasizing technology-centric improvements, highlight the initial perception of blockchain as a novel technology requiring thorough technical feasibility assessment before broader implementation.

Shifting its focus from technological assessment to real-world implementation, the second phase of blockchain research (2021-present) witnessed an increased emphasis on sector-specific utilization. Two primary case studies emerged: healthcare and public services. Within healthcare, the research addressed specific areas like pharmaceutical supply chain enhancement (Alshahrani and Alshahrani 2021), broader healthcare adoption (Balasubramanian *et al*., 2021), regulatory challenges (Sanda *et al*., 2022), and electronic health record management (Alzahrani *et al*., 2023). Public service studies explored digital government projects (Yang *et al*., 2022) and energy sector regulatory frameworks for blockchain adoption (Karisma and Tehrani 2023). Notably, each study proposed a sector-specific model for assessing blockchain implementation readiness, highlighting the shift towards practical application evaluation. Within the healthcare sector, assessment frameworks for blockchain readiness have evolved significantly. Alshahrani and Alshahrani (2021), categorized their quantitative data-driven framework into inhibitors, facilitators, and compromisers, offering a concise but independent analysis.

Table 1. Domains and findings from the literature on blockchain implementation assessment

Paper	Domain	Findings
(Alzahrani *et al*., 2023)	Electronic Health Record System Management	Two real-world case studies in two healthcare organizations have validated a readiness assessment model with 17 factors and 5 perspectives.
(Karisma and Tehrani, 2023)	Regulation of Blockchain Adoption in the Energy Sector	Comprehensive regulatory readiness assessment framework to assess countries' regulatory readiness levels.
(Sanda *et al*., 2022)	Regulations for Blockchain Adoption in Healthcare	A blockchain readiness assessment framework that incorporates all the different social and economic factors and involves all stakeholders. The proposal is applied to the Portuguese healthcare sector.
(Yang *et al*., 2022)	Digital Government Public Service Projects	A blockchain technology application maturity evaluation system consisting of five leading indicators.
(Balasubramanian *et al*., 2021)	Blockchain Adoption in Healthcare	A readiness assessment framework that covers the complex interactions of underlying factors, social structures, and institutional mechanisms and includes all key stakeholders.
(Alshahrani and Alshahrani, 2021)	Pharmaceutical Industry Improvement	The assessment framework is divided into three factors: inhibitors, facilitators, and compromisers.
(Ozdemir *et al*., 2020)	Travel and tourism industry	The primary criteria for assessing various distributed applications are blockchain governance models, blockchain platforms, consensus types, the use of cryptocurrencies, smart contracts, and tokens.
(Jin *et al*., 2019)	Sustainable blockchain products	A new Pythagorean fuzzy linguistic MADM model is used to calculate the selection of the most desirable sustainable blockchain products numerically.
(Lu *et al*., 2019)	Anonymity of blockchain networks	Anonymity Assessment Model based on Bayesian Network.
(Gupta Gourisetti *et al*., 2019)	Blockchain cybersecurity vulnerabilities	Evaluated rank-weight methods based on rank sum, reciprocal rank, rank exponent, and rank order centroid.

In contrast, Balasubramanian *et al*. (2021) proposed a more intricate framework acknowledging the complex interplay of underlying factors. This framework was further employed by Sanda *et al*. (2022), who emphasized comprehensive stakeholder engagement and incorporated diverse social and economic aspects, highlighting the pivotal role of regulators and governments in establishing a globally applicable regulatory landscape for blockchain healthcare adoption. Expanding beyond healthcare, Alzahrani *et al*. (2023) identified 17 crucial factors affecting blockchain adoption across five perspectives: financial, social, technical, organizational, and regulatory/legal. Among these, regulatory compliance, uncertainty, budget availability, management support, security/privacy, and financial risk/uncertainty were deemed particularly significant for organizational readiness.

In the public service sector, research has shifted towards evaluating the application maturity of blockchain in real-world digital projects (Yang *et al*., 2022). They proposed a novel assessment system encompassing five key indicators: application requirements, data security, process complexity, application ecology, and technical performance. Their findings revealed that "technical performance requirements" and "process complexity" pose critical challenges for maturity in government-oriented and pilot projects. Recognizing the regulatory hurdles amidst blockchain's potential, Karisma and Tehrani (2023) propose a comprehensive Regulatory Readiness Assessment Framework (RAF) to evaluate a country's preparedness for blockchain adoption. This RAF is touted as a valuable tool for assessing the maturity, completeness, and efficacy of existing regulatory mechanisms, ultimately contributing to both the practical and theoretical advancement of blockchain technology.

A comprehensive literature review reveals several vital areas for assessing blockchain technology implementation readiness: technical maturity, domain suitability, regulatory landscape, and stakeholder dynamics. While frameworks for individual aspects have emerged, a glaring gap exists in a unified model encompassing all these determinants. Addressing this lacuna by developing a holistic, operational model for assessing blockchain implementation readiness across diverse real-world case studies is a critical future research priority.

Integrated Assessment Model for Implementation of Blockchain-based System

Drawing upon the concept of interdependent components influencing implementation assessment within a specific context (Moullin *et al*., 2020), we present a novel Integrated Assessment Model for implementing a Blockchain-based System. Figure 2 visually depicts this five-layered model, inspired by the state of the digital business ecosystem/DBE (Nachira *et al*., 2007). Each layer delves into critical components that determine blockchain implementation readiness: foundational infrastructure, digital capabilities, process alignment, organizational readiness, legal and regulatory frameworks and technology usability. This structured approach facilitates a comprehensive and holistic evaluation of the factors crucial for successful blockchain technology integration in diverse real-world applications.

Operationalizing blockchain implementation readiness necessitates a comprehensive assessment addressing five crucial layers: technology, business, data, regulatory, and user interface. We propose an integrated assessment model encompassing these layers along with a corresponding instrument tailor-made for each layer. Each instrument delves into specific elements pertinent to its associated layer, enabling a deep-dive evaluation of the system's readiness. This multi-layered approach offers developers and stakeholders in the real world a more holistic and operationally viable tool for gauging blockchain implementation feasibility, ultimately facilitating successful real-world integration.

The technology layer of our integrated assessment model delves into the suitability of blockchain characteristics relative to specific system requirements. We focus on requirement engineering as the key evaluation object, encompassing both functional and non-functional elements. Assessing the alignment between blockchain functionalities and business needs, including platform selection and performance evaluation, is crucial for successful technology adaptation (Almeshal and Alhogail 2021). Suitability within functional requirements is a primary focus, considering its relationship to addressed use cases. Scalability challenges are also critical, assessed through parameters like block size, creation rate, and transaction speed (Khan *et al.*, 2021). Additionally, features like smart contracts, tokenization, and cryptographic hashing are evaluated for suitability, considering potential multi-blockchain integrations (Gourisetti *et al.*, 2020). Selecting the optimal blockchain type paves the way for assessing non-functional requirements like interoperability, security, and performance.

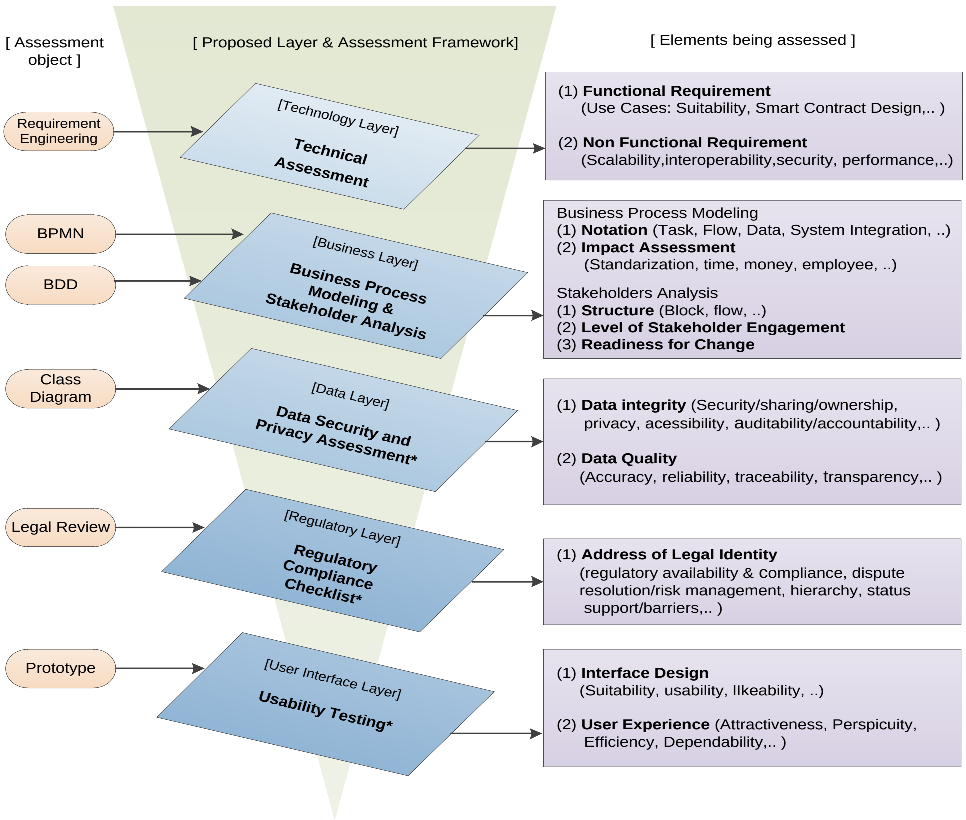

Figure 2. Integrated integrated assessment model for implementation of blockchain-based system

Operationalizing blockchain in the business layer demands a nuanced understanding of both its characteristics and the corresponding business processes. Blockchain integration is not simply a technological overlay; it must address existing system dynamics and stakeholder interactions to overcome challenges like time inconsistencies and consensus bias (Viriyasitavat and Hoonsopon 2019). We argue that the business layer is the pivotal element in our integrated assessment model due to its cascading impact on other layers and ultimate influence on overall performance. Here, we propose assessing two key objects: Business Process Model and Notation (BPMN) to map stakeholder-system interactions and Block Definition Diagram (BDD) to gauge stakeholder engagement and readiness for change. This comprehensive approach ensures that integration aligns with existing business realities and fosters stakeholder buy-in, laying the foundation for successful blockchain implementation.

Our integrated assessment model leverages two key tools within the business layer: the BPMN and the BDD. BPMN, a widely accepted industry standard for managing business processes (Dumas *et al*., 2018), provides a common framework for modeling how the real world interacts through tasks, flows, and data (Zarour *et al*., 2020). It allows us to assess the efficiency of time, money, and human resources within the planned blockchain-based system. BDD, on the other hand, facilitates the identification and evaluation of critical stakeholders (Bernstein *et al*., 2020). This visual tool allows us to assess stakeholder support for the project and their potential impact on its implementation. We further categorize stakeholder engagement and readiness for change into different levels – individual, company, industry, and society – reflecting the various scales at which stakeholders can contribute to the project's sustainability and the levels of collaboration required (Gonzalez-Porras *et al*., 2021). Together, BPMN and BDD provide a comprehensive understanding of the business landscape and stakeholder dynamics, ensuring that blockchain integration aligns with existing realities and fosters buy-in for successful implementation.

Ensuring the integrity and security of data within a blockchain-based system necessitates a robust assessment of the data layer. We propose a comprehensive evaluation focusing on key elements like basic security requirements, threat mitigation strategies, and incident response protocols (Barmawi, 2022). This safeguards data against threats, enabling effective accountability and attribution of malicious activities (Jeyakumar *et al.*, 2023). Our assessment delves into data confidentiality, rigorously testing mechanisms like encryption, identity authentication, access control, and attribute-based encryption offered by blockchain technology. Data integrity is also paramount, and we assess the system's ability to provide an immutable audit trail of all transactions, thereby enhancing transparency and accountability (White *et al*., 2020). Standardizing data assessment at this level lays the foundation for higher-level data abstractions, ultimately improving the audibility and intuitiveness of blockchain-based systems (Vinceslas *et al.*, 2023).

Navigating the legal landscape of blockchain implementation necessitates meticulous attention to the regulatory layer. Assessing regulatory certainty becomes crucial at the prototype stage, where the foundation laid by previous layer evaluations can be leveraged for wider adoption (Al-khateeb, 2021). However, despite most jurisdictions implementing frameworks, limitations often focus solely on the financial aspects of cryptocurrency-based operations (Ellul *et al*., 2020). This underscores the importance of contextualizing specific use cases, business processes, and data exchange within available regulations. Furthermore, standardized regulatory measures are key to ensuring accessibility and validation once specific regulations are identified (Eyassu, 2019). Our proposed Regulatory Compliance Checklist assessment addresses this need by verifying the viability of technology integration within specific business contexts. Ultimately, a clear regulatory environment fostered by readily available regulations is the bedrock upon which blockchain technology can realize its full potential (Jiaying, 2022).

Recognizing the user interface's significant influence on blockchain implementation readiness, we propose assessing this crucial layer. Effective user interface design is vital for facilitating user understanding and engagement with the application (Jang *et al*., 2020). To incorporate user feedback into the development process, we propose a usability testing assessment instrument. This user-centric approach addresses the identified gap in blockchain research, where user involvement in evaluation tends to be lower than in non-blockchain studies (Tharatipyakul and Pongnumkul, 2021). By testing the developed prototype through this lens, we aim to comprehensively assess the system's readiness for implementation, encompassing both its technical development and users' social and situational contexts. This integrated evaluation provides a holistic understanding of user experience and ensures that the system is aligned with real-world user needs and capabilities.

Our proposed integrated assessment model for blockchain implementation stands out for its comprehensive five-layer structure, meticulously designed to address every critical aspect. The technology layer evaluates the suitability of blockchain functionalities like smart contracts and distributed ledgers to specific project requirements. The business layer focuses on seamless integration through tools like BPMN and BDD, ensuring efficient workflows and stakeholder engagement. Data security and privacy are prioritized in the data layer, safeguarding the system's integrity and reliability. Regulatory compliance is assessed in the fourth layer, ensuring the system adheres to existing legal frameworks and enabling broader adoption. Finally, the user interface layer emphasizes user-friendly design, guaranteeing intuitive access and usability. This holistic model empowers developers and stakeholders to conduct a thorough evaluation, encompassing both technical feasibility and crucial social and regulatory considerations. Ultimately, this comprehensive approach serves as a cornerstone for successful blockchain implementation, ensuring alignment with real-world needs and maximizing the technology's potential.

Case Study: Supply Chain of Kintamani Coffee Agroindustry

Integrating blockchain into complex, multi-stakeholder supply chains presents both technical and business challenges. Technically, seamless connections and interoperability between disparate systems are paramount (Bouras *et al.*, 2022; Goodarzian *et al.*, 2022). From a business perspective, a robust traceability system is necessary to address concerns like illegal practices, sustainability, operational efficiency, supply chain coordination, and market trends (Hastig and Sodhi, 2020). However, cost optimization for the chosen blockchain architecture remains a crucial consideration for developers, organizations, and users (Schmeiss *et al.*, 2019). Assessing this business process layer necessitates systematically identifying and prioritizing stakeholder engagement to ensure inclusivity and maximize organizational sustainability, both in strategic analysis and practical implementation (Franklin, 2020). This systematic approach ensures seamless integration of blockchain technology while fostering collaboration and addressing the diverse needs within the supply chain network.

To validate the efficacy of our proposed integrated assessment model, an evaluation framework based on impact analysis will be employed (Nilsen, 2020). This stage operationalizes the model and translates its theoretical foundations into real-world practice. Consequently, we will leverage our prior case study of developing a blockchain-based traceability information system for the Kintamani coffee agro-industry (Pradana *et al.*, 2020; Pradana *et al.*, 2023), as a practical demonstration of the model's effectiveness. Figure 3 exemplifies one facet of the business layer assessment: the identification and engagement of key stakeholders in the blockchain adoption process. This real-world application will provide empirical evidence of the model's capacity to address the identified research challenges, solidifying its practical utility in facilitating successful blockchain implementation.

Within the Kintamani Coffee agro-industry, the blockchain-based traceability system interacts with a diverse network of stakeholders: farmers, processors, distributors, roasters, coffee shops, and end customers (generalized as users). Beyond users, system development engages government agencies, associations, experts, and researchers.

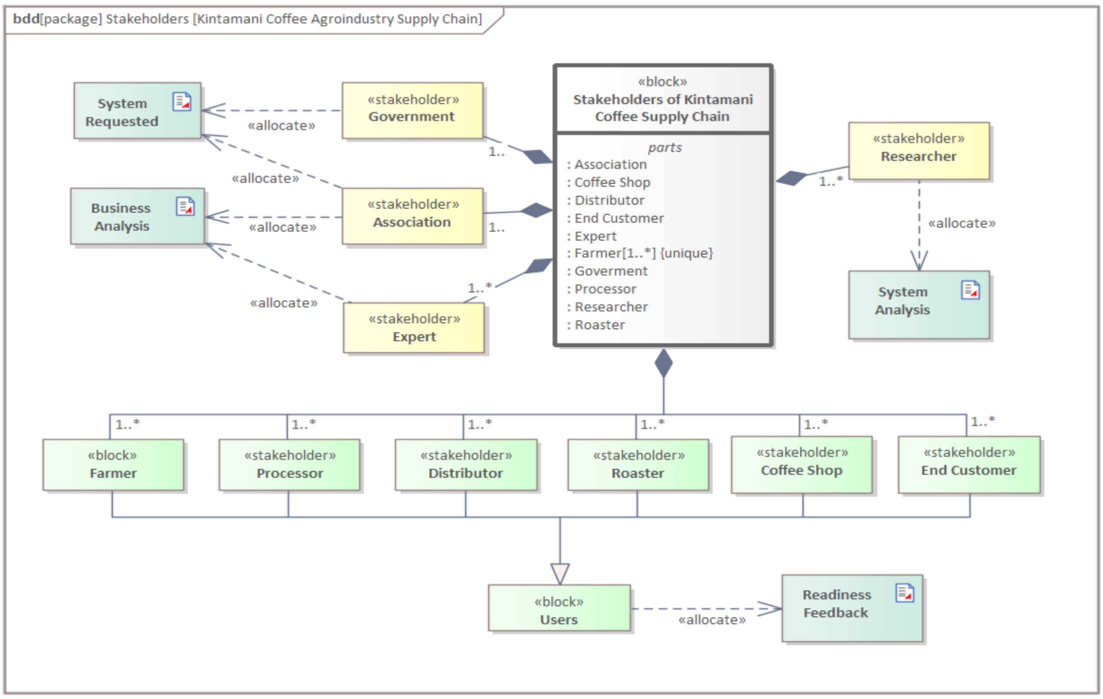

Figure 3. Stakeholders engagement di Kintamani Coffee supply chain for development of blockchain-based traceability system

As a public-facing system, initial requirements were primarily elicited through discussions with the government, the Kintamani Coffee Geographical Indication Protection Society, and relevant associations. These were then refined into detailed business requirements with the assistance of associations and experts. Finally, as researchers, we employed requirement engineering to translate these requirements into the system architecture, iteratively making improvements based on user readiness feedback.

To delve deeper into the Kintamani coffee agro-industry's readiness for a blockchain-based traceability system, we employed SEM-PLS analysis based on quantitative survey data collected in the field. This approach allowed us to gauge user feedback, a crucial element in assessing readiness to change within the business layer, which ultimately drives the willingness to implement blockchain technology. Notably, five exogenous variables indirectly represent the five proposed layers of our integrated assessment model: (1) technology compatibility (TC) for the technology layer, (2) top management support (TOP) for the business layer, (3) security concern (SC) for the data layer, (4) government policy (GP) for the regulatory layer, and (5) perceived ease of use (PEU) for the user interface layer. Blockchain adoption intention (AI) serves as the endogenous variable, representing the primary objective of the analysis. Figure 4 visually depicts the Structural Model Assessments output from the SEM-PLS analysis, providing insights into the complex interplay between these factors and their influence on blockchain adoption within the Kintamani coffee context. Our SEM-PLS analysis, with an adjusted R-squared value of 0.843, suggests that the five proposed latent variables successfully explain 84.3% of the variance in user intention to adopt blockchain. Examining the individual path coefficients reveals that technology compatibility (TC) exhibits the strongest influence on blockchain adoption intention, as evidenced by its t-value exceeding 1.96 ($p < 0.05$). This indicates that users, perhaps unsurprisingly, perceive the technology layer and its constituent elements as the most critical factor driving their willingness to embrace blockchain. However, top management support (TOP), representing the business layer, surprisingly shows the weakest influence. This result implies that the readiness to change within the organizational context remains suboptimal, suggesting a need for improvement in the business layer before full-scale implementation. To gain further insights, Figure 5 visually maps each statement within the five latent variables based on its importance and performance, offering a nuanced understanding of how specific user perceptions contribute to the overall adoption intention.

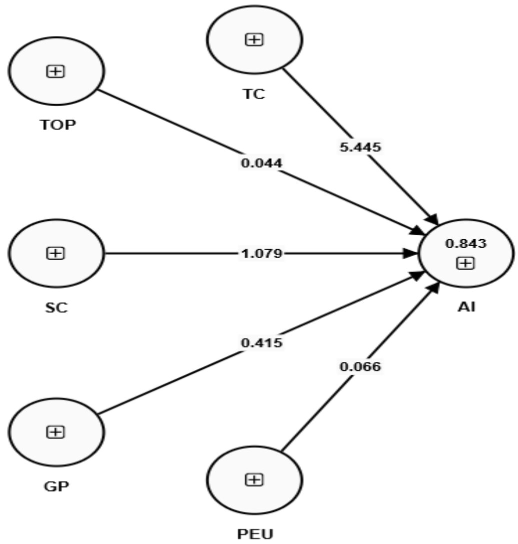

Figure 4. Assessment variables of the blockchain adoption intention layer in the Kintamani Coffee traceability system

To gain deeper insights beyond traditional path analysis, we employed Importance-Performance Map Analysis (IPMA), which considers both the relative importance (path coefficient) and absolute performance (mean value) of constructs and indicators (Ringle and Sarstedt, 2016). Figure 5 visualizes our IPMA results categorized into four quadrants based on combined importance-performance values: high-high (Q1), low-high (Q2), low-low (Q3), and high-low (Q4). Notably, all elements within the technology compatibility (TC) construct reside in Q1, indicating high performance and exceeding expectations in influencing blockchain adoption intention. This suggests that users perceive the technology layer as the most critical driver of adoption. Conversely, the remaining constructs (security concern, government policy, perceived ease of use, and top management support) occupy Q2, signifying high performance but limited contribution to the target variable. This implies that despite individual elements within these constructs performing well, the data, regulatory, user interface, and business layers require further enhancement to significantly impact overall adoption intention. This analysis provides valuable insights into specific areas demanding improvement to maximize the success of blockchain implementation in the Kintamani coffee agro-industry.

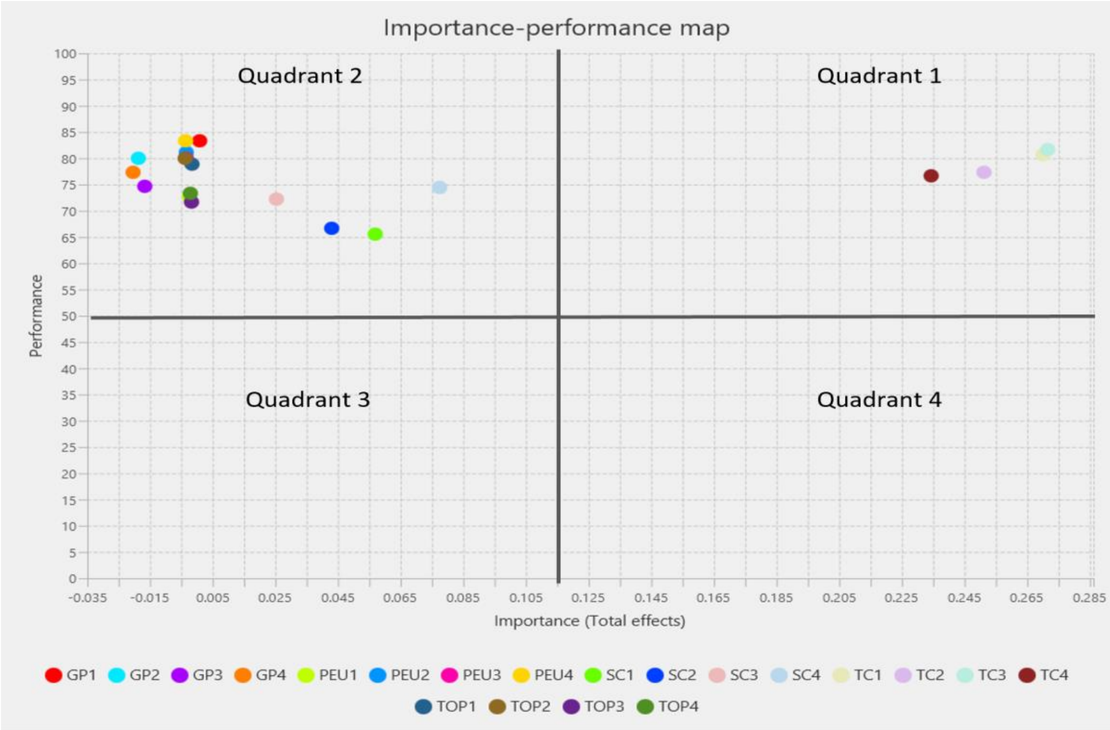

Figure 5. Results of Importance-performance Map Analysis (IPMA)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research undertook a comprehensive literature review and empirical analysis to identify the research gap in blockchain implementation assessment. From our review, a thematic evolution was discernible in the literature from a technologically focused perspective to sector-specific, practical applications in recent years. The challenges of scalability and privacy emerged as persistent concerns, while sector-specific studies in healthcare and public services highlighted the importance of regulatory frameworks, stakeholder engagement, and readiness assessment. Our proposed five-layered Integrated Assessment Model addresses these multifaceted challenges by providing a holistic framework that systematically evaluates blockchain readiness in real-world applications.

Our case study on the Kintamani coffee agro-industry validates this framework through a rigorous SEM-PLS analysis, revealing that technological capability is the most significant factor influencing blockchain adoption intention. However, the business layer's relatively weaker (Q2) influence underscores the need to enhance organizational readiness. The Importance-Performance Map Analysis (IPMA) further identifies areas requiring improvement, emphasizing optimizing regulatory frameworks, data security, and user interface design.

In conclusion, this study bridges the gap in blockchain implementation assessment by offering an integrated framework and delivering examples based on continuous research studies in blockchain-based system development for the traceability of Kintamani coffee. The Integrated Assessment Model lays the groundwork for future research to refine and adapt its layered approach for diverse domains, ultimately guiding stakeholders to make informed decisions, overcome adoption barriers, and maximize blockchain's transformative potential.

Recommendations

In light of these findings, we recommend several areas for future research that have not yet been comprehensively explored. First, more context-specific integrated assessment models must be tailored to niche sectors beyond this research's case studies. Other sectors, besides health care and public services, could benefit from frameworks that address their unique operational challenges and regulatory environments, such as sectors in education, finance, and environmental sustainability. Additionally, future research should expand the scope to encompass emerging blockchain frameworks, such as cross-chain interoperability and decentralized autonomous organizations, ensuring that assessment models remain relevant to evolving technologies.

Moreover, a focus on previously unreachable contexts is crucial. This attention includes assessing blockchain adoption in developing regions, where infrastructural challenges and governance issues pose distinct hurdles. Addressing these gaps requires multidisciplinary approaches considering sociocultural and economic factors alongside technological capabilities. Finally, future studies should prioritize longitudinal research to capture the dynamic evolution of blockchain implementation, providing actionable insights into long-term adoption trends and barriers. Ultimately, these recommendations aim to foster a holistic understanding of blockchain readiness, ensuring that frameworks are comprehensive, adaptable, and inclusive of diverse global contexts.

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REFERENCES

Al-khateeb BA. 2021. Regulatory Standards and Measures: Panacea for Blockchain Technology Acceptability. In A. Sghari & K. Mezghani (Eds.), *Influence of FinTech on Management Transformation*, IGI Global: 54–72. https://doi.org/10.4018/978-1-7998-7110-1.ch003

Almeshal TA, and Alhogail AA. 2021. Blockchain for businesses: a scoping review of suitability evaluations frameworks. *IEEE Access*. 9: 155425–155442. https://doi.org/10.1109/ACCESS.2021.3128608

Alshahrani W, and Alshahrani R. 2021. Assessment of blockchain technology application in the improvement of pharmaceutical industry. *2021 International Conference of Women in Data Science at Taif University, WiDSTaif 2021*. Al Hawiyah, Ta'if. Saudi Arabia: March 30-31, 2021 https://doi.org/10.1109/WIDSTAIF52235.2021.9430210

Alzahrani S, Daim T, and Choo KKR. 2023. Assessment of the blockchain technology adoption for the management of the electronic health record systems. *IEEE Transactions on Engineering Management*. 70(8): 2846–2863. https://doi.org/10.1109/TEM.2022.3158185

Araballi S, and Devaki P. 2023. A critical review of agri-food supply management with traceability and transparency using blockchain technology. In: Hemanth, J., Pelusi, D., Chen, J.IZ. (eds) *Intelligent Cyber Physical Systems and Internet of Things. ICoICI 2022. Engineering Cyber-Physical Systems and Critical Infrastructures*, vol 3. Springer, Cham: 239-250. https://doi.org/10.1007/978-3-031-18497-0_18

Balasubramanian S, Shukla V, Sethi JS, Islam N, and Saloum R. 2021. A readiness assessment framework for blockchain adoption: a healthcare case study. *Technological Forecasting and Social Change*. 165: 120536. https://doi.org/10.1016/j.techfore.2020.120536

Barmawi AM. 2022. Security basics on blockchain. In Veuger, J (ed.), *Blockchain Technology and Applications III*. New York, USA: Nova Science Publishers, Inc.

Bernstein SL, Weiss J, and Curry L. 2020. Visualizing implementation: contextual and organizational support mapping of stakeholders (COSMOS). *Implementation Science Communications*. 1(1): 1–11. https://doi.org/10.1186/s43058-020-00030-8

Bouras A, Khalil I, and Aouni B. 2022. *Blockchain Driven Supply Chains and Enterprise Information Systems*. Gewerbestrasse, Switzerland: Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-96154-1

Brendel AB, Marrone M, Trang S, Lichtenberg S, Kolbe LM. 2020. What to do for a literature review? - a synthesis of literature review practices. *26th Americas Conference on Information Systems, AMCIS 2020*. Virtual Conference: August 15-17, 2020.

Buterin V. 2013. Ethereum: the ultimate smart contract and decentralized application platform [White Paper].

Caro MP, Ali MS, Vecchio M, Giaffreda R. 2018. Blockchain-based traceability in agri-food supply chain management: a practical implementation. *IoT Vertical and Topical Summit on Agriculture*. Italy: May 8-9, 2018. https://doi.org/10.1109/IOT-TUSCANY.2018.8373021

Doody O and Noonan M. 2013. Preparing and conducting interviews to collect data. *Nurse researcher*. 20(5): 28–32. https://doi.org/10.7748/nr2013.05.20.5.28.e327

Dumas M, La-Rosa M, Mendling J, and Reijers HA. 2018. *Fundamentals of business process management: Second Edition*. Berlin, Germany: Springer-Verlag GmbH. https://doi.org/10.1007/978-3-662-56509-4

Durlak JA. 2014. Why program implementation is important. In Durlak JA & Ferrari JR (Eds.), *Program Implementation in Preventive Trials*. Routledge:5–18. https://doi.org/10.4324/9781315827704-7

Ellahi RM, Wood LC, and Bekhit AEDA. 2023. Blockchain-based frameworks for food traceability:a systematic review. *Foods*. 12(16): 1-28. https://doi.org/10.3390/foods12163026

Ellul J, Galea J, Ganado M, Mccarthy S, Pace GJ. 2020. Regulating blockchain, DLT and smart contracts: a technology regulator’s perspective. *ERA Forum*. 21(2): 209–220. https://doi.org/10.1007/s12027-020-00617-7

Eyassu SE. 2019. Overview of blockchain legislation and adoption: status and challenges. *Issues in Information Systems*. 20(1): 12–21. https://doi.org/10.48009/1_iis_2019_12-21

Fernandez JL and Hernandez C. 2019. *Practical*

Model-Based Systems Engineering. Artech House.

Franklin AL. 2020. *Stakeholder Engagement*. Gewerbestrasse, Switzerland:Springer Nature Switzerland AG. https://doi.org/10.4135/9781483381503.n1117

Gonzalez-porras L, Heikkinen A, Kujala J, Tapaninaho R. 2021. Stakeholder engagement in sustainability transitions. In Teerikangas S, Onkila T, Koistinen K, and Mäkelä M (eds.), *Research Handbook of Sustainability Agency*. Cheltenham, UK: Edward Elgar Publishing Ltd. https://doi.org/https://doi.org/10.4337/9781789906035

Goodarzian F, Abraham A, and Ghasemi P. 2022. Key success factors for blockchain implementation in supply chain management. In Mathiyazhagan K, Sreedharan VR, Mathivathanan D, Sunder V (eds.), *Blockchain in a Volatile-Uncertain-Complex-Ambiguous World*, *1st Edition*. Amsterdam, Netherlands: Elsevier Science. https://doi.org/10.1016/B978-0-323-89963-5.00003-4

Gourisetti SNG, Mylrea M, and Patangia H. 2020. Evaluation and demonstration of blockchain applicability framework. *IEEE Transactions on Engineering Management*. 67(4): 1142–1156. https://doi.org/10.1109/TEM.2019.2928280

Gupta GN, Mylrea M, and Patangia H. 2019. Application of rank-weight methods to blockchain cybersecurity vulnerability assessment framework. *IEEE 9th Annual Computing and Communication Workshop and Conference, CCWC 2019*. USA: January 7-9, 2019. https://doi.org/10.1109/CCWC.2019.8666518

Harrison H, Birks M, Franklin R, Mills J. 2017. Case study research: foundations and methodological orientations. *Forum Qualitative Sozialforschung*. 18(1).

Hastig GM and Sodhi MMS. 2020. Blockchain for supply chain traceability: business requirements and critical success factors. *Production and Operations Management*. 29(4): 935–954. https://doi.org/10.1111/poms.13147

Jang H, Han SH, and Kim JH. 2020. User perspectives on blockchain technology: user-centered evaluation and design strategies for DApps. *IEEE Access*. 8: 226213–226223. https://doi.org/10.1109/ACCESS.2020.3042822

Jeyakumar ST, Ko R, and Muthukkumarasamy V. 2023. A framework for user-centric visualisation of blockchain transactions in critical infrastructure. *Proceedings of the 5th ACM International Symposium on Blockchain and Secure Critical Infrastructure, BSCI '23*. Australia: July 10–14, 2023. https://doi.org/10.1145/3594556.3594624

Jiaying J. 2022. Technology-enabled co-regulation for blockchain implementation. *University of Pittsburgh Law Review*. 83(4): 829–892. https://doi.org/10.5195/LAWREVIEW.2022.876

Jin F, Pei L, Chen H, Langari R, Liu J. 2019. A novel decision-making model with pythagorean fuzzy linguistic information measures and its application to a sustainable blockchain product assessment problem. *Sustainability*. 11(20): 5630.https://doi.org/10.3390/su11205630

Jorika V and Medishetty N. 2023. Demystifying blockchain: a critical analysis of application characteristics in different domains. *Journal of Advances in Information Technology*. 14(4): 718–728. https://doi.org/10.12720/jait.14.4.718-728

Karisma K and Tehrani PM. 2023. Blockchain adoption in the energy sector: a comprehensive regulatory readiness assessment framework to assess the regulatory readiness levels of countries. *Lecture Notes in Networks and Systems*. 595: 454–460. https://doi.org/10.1007/978-3-031-21229-1_42

Khan KM, Arshad J, Khan MM, Nasir MH. 2021. An empirical investigation of blockchain scalability. *EAI/Springer Innovations in Communication and Computing*. https://doi.org/10.1007/978-3-030-75107-4_5

Kobrin JL, Karvonen M, Clark A, and Thompson WJ. 2022. Developing and refining a model for measuring implementation fidelity for an instructionally embedded assessment system. *Practical Assessment, Research and Evaluation*. 27:24. https://doi.org/10.3102/1681034

Kulkarni PM, Rachh RR, and Nayak GS. 2023. Blockchain implementation, challenges and issues. In Shukla VK, Vyas S, Gupta S, and Dubey S (Eds.), *Emerging Applications of Blockchain Technology*. Nova Science Publishers: 41-56. https://doi.org/https://doi.org/10.52305/CFEV0448

Lokshina IV and Lanting CJM. 2021. Revisiting state-of-the-art applications of the blockchain technology: analysis of unresolved issues and potential development. Kryvinska, N., Greguš, M. (eds), *Studies in Systems, Decision and Control*. https://doi.org/10.1007/978-3-030-62151-3_10

Lu T, Yan R, Lei M, Lin Z. 2019. AABN: Anonymity assessment model based on bayesian network with application to blockchain. *China Communications*. 16(6): 55–68. https://doi.org/10.23919/j.cc.2019.06.005

Marchese A, and Tomarchio O. 2022. A blockchain-based system for agri-food supply chain traceability management. *SN Computer Science*. 3(4): 279. https://doi.org/10.1007/s42979-022-01148-3

Menon S and Jain K. 2021. Blockchain technology for transparency in agri-food supply chain: use cases, limitations, and future directions. *IEEE Transactions on Engineering Management*. 71: 106–120. https://doi.org/10.1109/TEM.2021.3110903

Moullin JC, Dickson KS, Stadnick NA, Albers B, Nilsen, P, Broder-Fingert S, Mukasa B, Aarons GA. 2020. Ten recommendations for using implementation frameworks in research and practice. *Implementation Science Communications*. 1(1): 1–12. https://doi.org/10.1186/s43058-020-00023-7

Nachira F, Nicolai A, Dini P, Louarn ML, Leon LR. 2007. *Digital Business Ecosystems. Luxembourg*, Europe: European Commission. http://www.digital-ecosystems.org/dbe-book-2007

Nakamoto S. 2008. Bitcoin: a peer-to-peer electronic cash system. 1–9 [White Paper]. https://doi.org/10.1162/ARTL_a_00247

Nilsen P. 2020. Overview of theories, models and frameworks in implementation science. In Nilsen P and Birken SA (eds.), *Handbook on Implementation Science*. Massachusetts, USA: Edward Elgar Publishing, Inc. https://doi.org/10.4337/9781788975995.00008

Nilsen P. 2022. Theories, models, and frameworks in implementation science: a taxonomy. In Rapport F, Williams R, and Braithwaite J (eds.), *Implementation Science: The Key Concepts*. Oxfordshire, UK: Routledge, Taylor & Francis Group. https://doi.org/10.4324/9781003109945-10

Ozdemir AI, Ar IM, and Erol I. 2020. Assessment of blockchain applications in travel and tourism industry. *Quality and Quantity*. 54(5–6): 1549–1563. https://doi.org/10.1007/s11135-019-00901-w

Patnaik S, and Pandey SC. 2019. Case study research. In Subudhi RN, and Mishra S (ed.), *Methodological Issues in Management Research: Advances, Challenges, and the Way Ahead*. Leeds, UK: Emerald Publishing. https://doi.org/10.1108/978-1-78973-973-220191011

Pradana IGMT, Djatna T, Hermadi I, Yuliasih I. 2023. Blockchain-based traceability system for indonesian coffee digital business ecosystem. *International Journal of Engineering, Transactions B: Applications,* 36(5): 879–893. https://doi.org/10.5829/ije.2023.36.05b.05

Pradana IGMT, Djatna T, and Hermadi I. 2020. Blockchain modeling for traceability information system in supply chain of coffee agroindustry. *2020 International Conference on Advanced Computer Science and Information Systems, ICACSIS 2020*, 217–224. https://doi.org/10.1109/ICACSIS51025.2020.9263214

Queiroz MM, Telles R, and Bonilla SH. 2019. Blockchain and supply chain management integration: a systematic review of the literature. *Supply Chain Management: An international journal, 25(2): 241-254*. https://doi.org/10.1108/SCM-03-2018-0143

Ringle CM and Sarstedt M. 2016. Gain more insight from your PLS-SEM results the importance-performance map analysis. *Industrial Management and Data Systems*. 116(9): 1865–1886. https://doi.org/10.1108/IMDS-10-2015-0449

Rogerson M and Parry GC. 2020. Blockchain: case studies in food supply chain visibility. *Supply Chain Management*. 25(5): 601–614. https://doi.org/10.1108/SCM-08-2019-0300

Sabol M, Hair J, Cepeda G, Roldán JL, Chong AYL. 2023. PLS-SEM in information systems: seizing the opportunity and marching ahead full speed to adopt methodological updates. *Industrial Management and Data Systems*. 123(12): 2997–3017. https://doi.org/10.1108/IMDS-07-2023-0429

Sanda O, Pavlidis M, and Polatidis N. 2022. A regulatory readiness assessment framework for blockchain adoption in healthcare. *Digital*. 2(1): 65–87. https://doi.org/10.3390/digital2010005

Schmeiss J, Hoelzle K, and Tech RPG. 2019. Designing governance mechanisms in platform ecosystems: addressing the paradox of openness through blockchain technology. *California Management Review*. 62(1): 121–143. https://doi.org/10.1177/0008125619883618

Singh B, Pahwa R, Tanwar HO, Gupta N. 2021. Blockchain applications. In Tyagi SS, and Bhatia, S (eds.), *Blockchain for Business: How It Works and Creates Value*. Beverly, MA: Scrivener Publishing LLC. https://doi.org/10.1002/9781119711063.ch14

Tan Y, Huang X, and Li W. 2023. Does blockchain-based traceability system guarantee information authenticity? an evolutionary game approach. *International Journal of Production Economics*. 264(May): 108974. https://doi.org/10.1016/j.ijpe.2023.108974

Tharatipyakul A and Pongnumkul S. 2021. User interface of blockchain-based agri-food traceability applications: a review. *IEEE Access*. 9: 82909–82929. https://doi.org/10.1109/ACCESS.2021.3085982

Vinceslas L, Dogan S, Sundareshwar S, Kondoz AM. 2023. Abstracting data in distributed ledger systems for higher level analytics and visualizations. *Future Internet*. 15(1): 1–15.

https://doi.org/10.3390/fi15010033

Viriyasitavat W and Hoonsopon D. 2019. Blockchain characteristics and consensus in modern business processes. *Journal of Industrial Information Integration*. 13: 32–39. https://doi.org/10.1016/j.jii.2018.07.004

White BS, King CG, and Holladay J. 2020. Blockchain security risk assessment and the auditor. *Journal of Corporate Accounting and Finance*. 31(2): 47–53. https://doi.org/10.1002/jcaf.22433

Xu S, Zhao X, and Liu Z. 2020. The impact of blockchain technology on the cost of food traceability supply chain. *2020 International Conference on Green Development and Environmental Science and Technology*. China: September 18-20, 2020. https://doi.org/10.1088/1755-1315/615/1/012003

Yang Y, Shi Y, and Wang T. 2022. Blockchain technology application maturity assessment model for digital government public service projects. *International Journal of Crowd Science*. 6(4): 184–194: https://doi.org/10.26599/IJCS.2022.9100025

Zarour K, Benmerzoug D, Guermouche N, Drira K. 2020. A systematic literature review on BPMN extensions. *Business Process Management Journal*. 26(6): 1473–1503. https://doi.org/10.1108/BPMJ-01-2019-0040