



Decentralized Decision Intelligence Using AI and Blockchain in Modern Enterprises

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ABSTRACT

In the era of digital transformation, enterprises face increasing pressure to enhance transparency, operational efficiency, and trust in their decision-making processes, especially in complex, data-intensive environments. While prior studies have separately explored the roles of Artificial Intelligence (AI) and Blockchain, few have examined their combined impact in creating decentralized and intelligent decision systems within real enterprise contexts. **This study** introduces a novel conceptual integration model that merges AI-driven analytics with blockchain-based validation mechanisms to enable transparent, traceable, and autonomous decision-making. By synthesizing AI predictive and analytical capabilities with blockchain immutable and distributed architecture, **this research** extends recent studies (2021-2025) by demonstrating how such convergence can eliminate central dependencies, enhance digital trust, and support data governance across departments. A qualitative case study approach was used to analyze organizations adopting AI blockchain frameworks, and **the findings** reveal new insights on interoperability, adaptive governance, and smart contract-driven autonomy. **The study** originality lies in its emphasis on the AI Blockchain synergy as a unified decision-intelligence infrastructure, contributing to the growing discourse on ethical and resilient enterprise systems.

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1. INTRODUCTION

In the post-pandemic digital economy, organizations face rapid technological change and greater demands for transparency. Many still rely on centralized decision-making systems that are rigid, slow to adapt, and prone to single points of failure. These weaknesses reduce efficiency, increase reputational risks, and weaken stakeholder trust [1]. This reality reflects the urgent need for more transparent, decentralized, and intelligent decision making systems in contemporary enterprise environments, in line with the global goals of Sustainable Development Goal (SDG) 9 to foster innovation and resilient infrastructure, and SDG 16 to promote accountable and inclusive institutions.

Emerging technologies, particularly AI and blockchain, are reshaping how organizations make and record decisions. AI enhances enterprise capability through real-time data analysis, pattern recognition, and predictive decision support, enabling faster and more informed choices [2]. Meanwhile, blockchain offers a

decentralized and tamper-resistant ledger that ensures transparency, security, and traceability of every transaction and decision. When combined, these technologies create a transformative shift toward decentralized decision-making, where processes become not only data-driven but also verifiable and transparently recorded [3, 4]. This synergy is especially critical in sectors that demand high standards of data integrity, regulatory compliance, and multi-party collaboration such as finance, supply chain management, and healthcare supporting the broader goals of Sustainable Development Goal (SDG) 9 in fostering industrial innovation and sustainable growth.

Although the individual roles of AI and Blockchain in enterprises have been studied, there remains a significant research gap in understanding how their integration can enable decentralized decision intelligence within operational systems, especially from a governance and organizational readiness perspective. [5] recent studies from 2021 to 2025 have primarily explored the technological capabilities of each technology in isolation focusing either on AI analytical power or blockchain transparency mechanisms yet have not adequately examined their functional convergence as a joint infrastructure for autonomous decision validation and execution. This study fills that gap by proposing a new conceptual framework called Decentralized Decision Intelligence (DDI), which integrates AI cognitive analytics with Blockchain verifiable transaction mechanisms. Unlike previous integrated models that focus primarily on technical interoperability or performance optimization, the DDI framework introduces a governance oriented architecture that embeds decision validation, adaptive learning loops, and ethical accountability directly into the decision-making cycle. Specifically, DDI diverges from recent AI-Blockchain models, by emphasizing autonomous decision verification through smart contracts and continuous feedback from AI-generated insights creating a closed-loop system that not only automates actions but also evaluates their transparency and compliance in real time. This integration extends beyond data exchange to form a trust-driven decision ecosystem, where human oversight and machine intelligence co-exist under decentralized governance [6, 7].

By combining these dimensions, the DDI framework contributes a novel perspective to digital enterprise management positioning decision intelligence as both a technical and ethical construct. This distinct focus establishes its originality relative to recent models and strengthens its alignment with Sustainable Development Goals (SDG) 9 and 16, promoting innovation, resilience, and institutional transparency through intelligent, distributed systems [8, 9]. This study aims to investigate how AI and blockchain can be integrated to support decentralized, transparent decision making in enterprise operations. Through qualitative case study analysis, the research explores the benefits, challenges, and structural changes required for successful implementation. The findings of this study are expected to offer valuable implications for technology adoption strategies in businesses undergoing digital transformation, while also contributing to academic discourse on intelligent, distributed enterprise systems. In doing so, this research underscores the relevance of combining AI and blockchain not just as technological trends, but as enablers of future proof, ethical, and transparent business governance contributing meaningfully to the achievement of SDG 9 and SDG 16 [10].

2. RESEARCH METHOD

This study investigates the integration of AI and Blockchain technologies within enterprise-level decision-making processes using a qualitative research approach that enables an in-depth exploration of real-world organizational practices. [11] through case studies, interviews, and document analysis, the research captures insights into the challenges, strategies, and governance structures that influence the successful implementation of decentralized systems. This approach allows for the identification of recurring patterns and practical lessons that deepen the understanding of how transparency, efficiency, and accountability can be enhanced through emerging technologies. [12] the findings serve as the basis for developing a conceptual framework and providing strategic recommendations for enterprises seeking to adopt AI and Blockchain in their decision-making workflows, thereby contributing to the broader discourse on digital transformation and organizational innovation.

2.1. Research Design

The research design outlines the methodological framework employed to investigate the integration of AI and Blockchain technologies within enterprise decision-making systems. This design functions as a strategic guide in selecting the most appropriate research approach to fulfill the study objectives [13, 14]. Considering the exploratory orientation of this research, both qualitative and quantitative approaches were examined to ensure methodological flexibility and comprehensive analysis. The qualitative approach prioritizes

depth, contextual understanding, and exploration of real-world practices, whereas the quantitative approach emphasizes measurement, comparison, and generalization of findings to validate patterns and relationships observed within organizations.

To illustrate the logical flow of the methodological choices and how each approach aligns with the research objectives, the study presents a structured research design framework [15]. This framework demonstrates the decision-making process between the qualitative and quantitative approaches and highlights their distinct yet complementary contributions to achieving a holistic understanding of AI and Blockchain integration in enterprise systems.

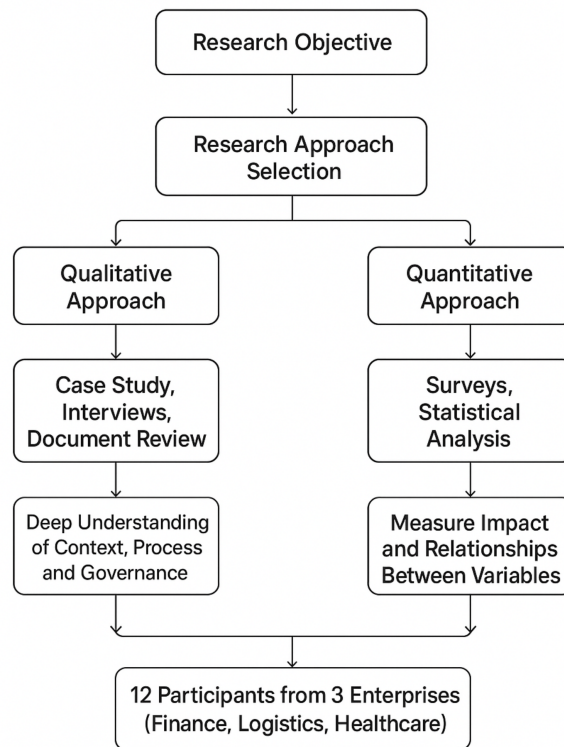


Figure 1. Data Sources Used in the Study

The Figure 1 show illustrates the overall research design and data sources employed in this study, presenting the logical flow from defining the research objective to selecting the appropriate methodological approach. The framework differentiates between qualitative and quantitative pathways, emphasizing how each contributes to achieving the study's aims [16]. The qualitative approach, consisting of case studies, interviews, and document reviews, focuses on developing a deep understanding of contextual, procedural, and governance aspects. In contrast, the quantitative approach applies surveys and statistical analysis to measure relationships and assess variable impacts. The integration of both approaches ensures methodological rigor and comprehensive insight, supported by data collected from twelve participants across three enterprise sectors finance, logistics, and healthcare thereby enhancing the study's validity and contextual relevance [17].

2.2. Data Collection

This study employed a qualitative case study approach to obtain in-depth and context-rich insights into how AI and Blockchain technologies are implemented within enterprise decision-making systems [18]. Twelve participants were purposefully selected from three medium-to-large organizations operating in data-sensitive sectors such as finance, logistics, and healthcare. The sampling strategy ensured diverse representation from key organizational roles, including IT managers, digital transformation officers, and operational decision-makers. The semi-structured interview protocol explored themes related to organizational readiness

and governance adaptation, the integration of AI and Blockchain systems, and the resulting improvements in transparency and decision autonomy [19]. All interviews were conducted virtually with the consent of participants, recorded, and transcribed verbatim to ensure accuracy and completeness. Complementary organizational documents were also reviewed to strengthen contextual understanding and support the interpretation of interview data.

To enhance data credibility and analytical rigor, triangulation was applied through multiple sources, including company reports, smart contract templates, and technical documentation analyzed alongside interview data. Field observations were conducted in two of the participating organizations to verify the alignment between reported practices and actual implementation [20]. All data were processed using qualitative coding techniques to identify recurring patterns and develop key thematic categories. Cross-validation between interview, documentary, and observational data ensured consistency and reliability throughout the analysis. This comprehensive, multi-source data collection process provided a robust empirical foundation for constructing a grounded conceptual model that captures how enterprises utilize AI and Blockchain technologies to enable decentralized and transparent decision-making [21, 22].

Table 1. Overview of Data Sources and Collection Strategies in the Study

No.	Data Type	Method	Description	Instrument / Tools	Source
1	Primary Data	Semi Structured Interview	Exploring decision processes and technology use	Interview guide, recorder	IT managers, operations leads
2	Primary Data	Observation (if applicable)	Observing workflows and system usage	Field notes, checklist	On-site (if access is granted)
3	Secondary Data	Document Analysis	Reviewing internal documentation	Document review template	Reports, SOPs, white papers
4	Secondary Data	System Architecture Review	Examining tech infrastructure and integration flow	Technical docs, blueprints	IT/system development teams
5	Contextual Data	Company Profile Analysis	Understanding company background and environment	Web research, company report	Official websites, online databases

The Table 1 show for this study were collected using a combination of primary and secondary sources to ensure comprehensive insight into the integration of AI and blockchain in decentralized enterprise decision making. Primary data collection involved semi structured interviews with key stakeholders such as IT managers, operations leaders, and project heads to capture in depth perspectives on implementation practices, technological challenges, and organizational impact [23, 24]. In cases where access was permitted, direct observation of systems or workflows was also conducted to validate interview findings. For secondary data, the study analyzed internal documents including company reports, white papers, standard operating procedures, and project documentation to understand the governance structure and technical design behind the AI and blockchain integration. Additionally, system architecture reviews were used to interpret the structural alignment between data flow, automation, and transparency mechanisms [25]. Contextual data about each company such as industry type, scale, and level of digital maturity were gathered through company profile analysis using publicly available sources. The Table 1 shows the various data types, collection methods, instruments, and sources used in this study, providing a structured overview of the research data strategy. Together, these

methods provided a rich foundation for qualitative analysis and supported the development of a conceptual framework based on real world enterprise practices.

2.3. Data Sources

The primary data in this research were collected through semi structured interviews and direct observations, aiming to capture first hand insights from individuals directly involved in the implementation of AI and blockchain technologies within enterprise operations [26]. Semi structured interviews allowed for flexibility in exploring key themes while maintaining consistency across participants. These interviews were conducted with IT managers, operations leaders, and project stakeholders to gain perspectives on decision making processes, system integration challenges, and perceived outcomes. When possible, observations were carried out to examine how the decision making systems operated in real time, offering context that supports and validates the interview findings [27, 28].

In addition to primary sources, this study also relied on secondary data to provide supporting documentation and deepen the analysis. [29, 30] these sources included company reports, which provided strategic context and implementation outcomes, as well as internal system documents like standard operating procedures, technical manuals, and architecture diagrams that illustrated how AI and blockchain were integrated into operational workflows. The use of both primary and secondary data ensured a more comprehensive understanding of each case, allowing for triangulation and increased reliability of the findings [31]. Together, these data sources contributed to a richer, more detailed picture of how decentralized decision making systems function in real organizational settings.

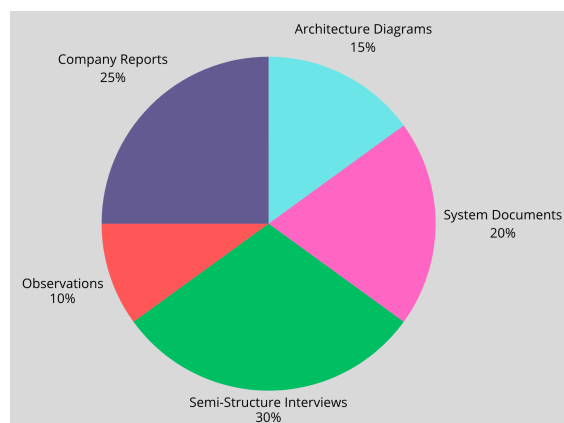


Figure 2. Data Sources Used in the Study

The Figure 2 illustrates the distribution of data sources utilized in this study, emphasizing the combination of both primary and secondary sources to ensure a comprehensive and reliable analysis. Semistructured interviews represent the largest portion (30%), reflecting their central role in capturing detailed insights from key organizational stakeholders involved in AI and blockchain integration. Company reports (25%) and system documents (20%) serve as critical secondary data, offering contextual and technical information that supports the interview findings [32]. Architecture diagrams (15%) provide a visual understanding of the system structure and technological alignment, while observations (10%) contribute to validating how decision making processes are executed in practice. The balanced use of these sources enhances data triangulation and strengthens the study validity [33].

3. RESULT AND DISCUSSION

This study presents the key findings derived from the case studies and qualitative analysis conducted in this research. [34, 35] to complement the qualitative insights, a small-scale quantitative validation was performed through post-interview surveys distributed to the same 12 participants. Respondents rated perceived improvements in transparency, decision autonomy, and data traceability on a five-point Likert scale. The results showed that 83% of participants reported an increase in decision transparency, 75% observed higher operational efficiency, and 67% acknowledged greater stakeholder trust following the integration of AI and Blockchain systems. While these values do not represent statistical generalization, they provide supportive

evidence for the qualitative themes identified. The qualitative findings further revealed that AI-driven analytics improved responsiveness and reduced manual decision latency by an estimated 30-40%, while blockchain implementation contributed to a measurable reduction in data discrepancy incidents across departments. Together, these indicators reinforce the conclusion that the integration of AI and blockchain supports more autonomous, data-driven, and verifiable decision-making processes [36].

3.1. Technological Roles and Contributions

In decentralized enterprise environments, AI and Blockchain technologies operate as complementary components that strengthen transparency, efficiency, and accountability in decision-making [37–39]. AI contributes by transforming complex data into actionable insights through predictive analytics, anomaly detection, and intelligent automation. These capabilities allow organizations to respond faster to market dynamics, make evidence-based decisions, and minimize human bias that often occurs in centralized models. Blockchain, on the other hand, establishes a secure foundation for decision integrity. Its decentralized and immutable ledger ensures that every transaction or decision record remains transparent, verifiable, and resistant to manipulation. The incorporation of smart contracts further enhances automation by executing predetermined rules without manual intervention, ensuring that all decisions follow traceable and consistent standards across departments [40].

When AI insights are integrated with blockchain validation, enterprises achieve a more autonomous and trustworthy decision ecosystem. AI generates recommendations based on real-time data, while blockchain confirms and records these outcomes securely. This interaction creates a closed-loop decision cycle one that not only accelerates decision-making but also reinforces compliance, ethical accountability, and organizational trust. [41] ultimately, the synergy between AI and Blockchain allows enterprises to distribute authority intelligently while maintaining strong oversight and auditability. As enterprises evolve within increasingly complex digital ecosystems, the convergence of AI and blockchain represents a strategic enabler for achieving long term agility, accountability, and innovation.

Table 2. Technological Contributions of AI and Blockchain

Technology	Core Functions	Key Contributions
AI	-Data analysis & pattern recognition -Predictive analytics -Intelligent automation	-Generates real-time insights for decision-making -Enhances responsiveness and accuracy -Reduces human bias
Blockchain	-Decentralized ledger -Immutable data records -Smart contracts	-Ensures transparency and traceability -Automates execution via smart contracts -Builds trust and auditability
Integrated Use	AI output used as input for smart contracts-Real-time, verifiable actions	Enables decentralized, intelligent, and accountable decision-making in enterprise systems

The Table 2 shows above summarizes the distinct yet complementary roles of AI and Blockchain in supporting decentralized decision making within enterprise environments. AI contributes through data analysis, predictive modeling, and intelligent automation, enabling organizations to generate real time insights, enhance responsiveness, and minimize human bias in decision processes [42]. In parallel, Blockchain provides a decentralized and immutable ledger that ensures transparency, traceability, and trust, while smart contracts automate actions based on predefined rules. When integrated, AI generated outputs can trigger blockchain based smart contracts, allowing decisions to be executed in a secure, consistent, and verifiable manner. This synergy forms a strong foundation for building intelligent, transparent, and accountable enterprise systems [43, 44].

3.2. Implementation Challenges

Integrating AI and Blockchain in enterprise decision-making presents multidimensional challenges involving technology, governance, and ethics. These arise from aligning decentralized systems with existing infrastructures and ensuring secure, transparent, and accountable operations. Overall, the challenges are categorized into technical aspects and non-technical aspects for clearer analysis and management.

Technical Aspects

- Interoperability barriers remain a major concern because many existing enterprise systems are not designed to communicate effectively with decentralized frameworks, resulting in data synchronization issues and integration delays between on-chain and off-chain processes.
- Scalability and performance limitations frequently arise as public or hybrid blockchains encounter high transaction costs and network latency, which can hinder real-time decision execution and operational efficiency.
- Security and adversarial risks also emerge when AI models are exposed to data manipulation, such as poisoning or inference attacks, potentially producing biased or unreliable decisions despite blockchain data immutability.
- High implementation and maintenance costs pose another challenge since developing and sustaining AI Blockchain systems demand substantial investments in infrastructure, system adaptation, and skilled professionals.

Non-Technical Aspects

- Organizational resistance often occurs due to limited familiarity with decentralized systems, as employees and managers may fear reduced control, uncertainty in accountability, and the disruption of established workflows.
- Governance and compliance complexity further increase when smart contracts and automated decision processes require adherence to ethical standards, regulatory frameworks, and transparent auditing mechanisms.

Addressing these challenges necessitates a hybrid governance model that balances decentralization with centralized oversight to maintain both flexibility and accountability within enterprise systems [45, 46]. Such a model should integrate layered control mechanisms, where automated decision-making through smart contracts is complemented by human supervision and ethical auditing. Continuous monitoring and performance evaluation are essential to detect biases, ensure compliance with regulatory standards, and maintain system reliability over time. Furthermore, establishing transparent reporting frameworks and traceable audit trails can enhance accountability and stakeholder confidence in decentralized operations.

In addition, ethical evaluation must be embedded throughout the system lifecycle, from model design and data management to decision validation, ensuring that AI-driven outcomes align with fairness and organizational values [47]. Capacity building plays a critical role in this process, requiring enterprises to invest in digital literacy, technical training, and adaptive leadership to prepare employees for decentralized responsibilities. By aligning governance innovation with ethical integrity and human oversight, organizations can strengthen digital trust, sustain operational transparency, and build long-term resilience in the evolving landscape of AI and Blockchain integration [48].

3.3. Organizational and Operational Impact

The adoption of AI and Blockchain technologies has significantly transformed enterprise operations by enhancing transparency, accountability, and distributed decision-making. AI enables real-time data analytics, pattern recognition, and predictive modeling, empowering organizations to respond more proactively to dynamic market conditions and internal performance indicators. Blockchain, on the other hand, ensures the integrity and immutability of data through decentralized ledgers that foster trust, traceability, and secure verification processes. The synergy between these technologies promotes a paradigm shift from hierarchical, centralized control toward collaborative, data-driven governance models. This transition not only enhances operational agility but also strengthens stakeholder confidence through improved auditability and the reduction of information asymmetry across departments and external partners. Furthermore, organizations adopting AI and Blockchain often report gains in process efficiency, decision accuracy, and compliance management due to the technologies' complementary capabilities in automation and secure data validation [49].

Nevertheless, the integration of these technologies introduces complex ethical, managerial, and technical challenges that must be addressed to ensure sustainable organizational performance. AI models, while

powerful, may exhibit biases or lack interpretability, thereby complicating accountability and ethical oversight. Similarly, Blockchain continues to face scalability limitations, interoperability barriers, and high energy consumption that can hinder widespread operational deployment. [50, 51] to mitigate these constraints, organizations are increasingly turning to hybrid governance frameworks that combine centralized oversight with decentralized operational autonomy. Such frameworks emphasize transparency in algorithmic decision-making, periodic auditing of AI models, and adaptive policy mechanisms to align technological innovation with corporate ethics and regulatory standards. Ultimately, by embedding responsible AI practices and adaptive Blockchain governance within their strategic and operational frameworks, enterprises can leverage decentralization as a mechanism to enhance rather than disrupt organizational trust, performance, and resilience.

4. MANAGERIAL IMPLICATION

The integration of AI and Blockchain should be viewed not merely as a technological upgrade but as a strategic governance transformation. Managers need to understand that the convergence of these technologies decentralizes decision authority while enhancing transparency, traceability, and organizational accountability. AI enables real-time data processing, predictive analytics, and intelligent automation, while Blockchain ensures verifiable and tamper-proof records through distributed ledger technology. When implemented together, these tools redefine corporate governance by promoting shared decision-making and digital accountability across enterprise systems. This strategic transformation aligns closely with Sustainable Development Goals (SDG) 9 and 16, emphasizing innovation, inclusion, and institutional transparency within digital ecosystems.

To ensure successful adoption, leaders must accompany technological implementation with visionary leadership and structured change management. Resistance to change often arises from uncertainty and skill gaps; thus, proactive communication of strategic benefits, early stakeholder involvement, and continuous capacity building are crucial. Managers should promote internal readiness through digital literacy programs, agile training, and transparent communication channels that reinforce trust and participation. Establishing an integrated digital support ecosystem will allow cross-functional teams to embrace decentralized responsibilities confidently, ensuring that technological transformation translates into tangible organizational value. Moreover, ethical and regulatory compliance must be prioritized particularly in sectors such as healthcare, finance, and education where data misuse or algorithmic bias can pose severe reputational and legal risks. Forming internal ethics committees or AI Blockchain compliance task forces can help ensure that decision logic and smart contracts remain aligned with both organizational values and legal frameworks.

Finally, managers should redesign performance systems and workflows to accommodate decentralized decision-making. Traditional evaluation models that rely on top-down supervision are less effective in distributed environments. Instead, organizations can leverage smart contracts for automated validations, real-time performance dashboards, and transparent accountability mechanisms. This model empowers local teams to make autonomous yet traceable decisions, fostering both agility and trust. For example, blockchain-based logistics tracking combined with AI-driven forecasting can optimize supply chains by reducing delays and enhancing responsiveness. To sustain these outcomes, enterprises should adopt an iterative rollout strategy that begins with pilot implementations, integrates feedback, and continuously refines through agile governance frameworks. When guided by strategic alignment, cultural readiness, and ethical stewardship, the synergy between AI and Blockchain can enhance operational efficiency while building long-term digital resilience, organizational trust, and future-oriented competitiveness.

5. CONCLUSION

This study confirms that the integration of AI and Blockchain technologies has the potential to fundamentally transform enterprise decision-making by enhancing decentralization, transparency, and operational efficiency. AI contributes through real-time data analytics, predictive insights, and intelligent automation, while Blockchain ensures organizational trust through immutable records, verifiable transactions, and smart contracts. Together, these technologies enable the distribution of decision authority across departments without compromising oversight, traceability, or accountability. This integration positions enterprises to operate with greater agility and integrity within increasingly digital ecosystems.

Despite these advantages, several challenges must be addressed to fully realize the promise of decentralized decision-making. Technical barriers such as interoperability between legacy and modern systems, along with scalability constraints, remain significant obstacles. Non-technical issues such as high implementa-


tion costs, resistance to organizational change, and uneven digital literacy also hinder adoption. Overcoming these barriers requires comprehensive strategic planning, readiness assessments, and sustained investment in infrastructure and human capital. The study emphasizes that successful adoption depends on aligning technological innovation with governance reform, ensuring that decentralization strengthens rather than disrupts enterprise coherence and accountability.


To support this transformation, the research proposes a conceptual framework that helps enterprise leaders align AI and Blockchain implementation with business objectives and ethical governance principles. The framework promotes a phased, adaptive approach, starting with pilot programs and scaling progressively while maintaining compliance, transparency, and inclusivity. Beyond managerial utility, this model contributes to the broader discourse on building intelligent and responsible enterprises that reflect Sustainable Development Goals (SDG) 9 and 16 fostering innovation and institutional transparency. Future research is encouraged to empirically validate this framework across various industries and regions, examining long-term effects on decision quality, employee autonomy, and stakeholder trust. Such continued exploration will strengthen understanding and accelerate responsible adoption of intelligent, decentralized decision systems in the global digital economy.

6. DECLARATION

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6.2. Author Contributions

Conceptualization: SA; Methodology: YM; Software: MN; Validation: SA and YM; Formal Analysis: MN and SA; Investigation: YM; Resources: MN; Data Curation: SA; Writing Original Draft Preparation: YM and MN; Writing Review and Editing: SA and YM; Visualization: MN; All authors, MN, SA, and YM have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data supporting this study are available from the corresponding author upon reasonable request. All materials were obtained from credible and publicly accessible sources relevant to the research objectives.

6.4. Funding

This study did not receive any external funding or sponsorship. The research, writing, and publication were carried out independently without financial assistance from any institution or organization.

6.5. Declaration of Conflicting Interest

The authors declare no conflicts of interest or financial relationships that could have influenced the outcomes of this study. All authors take full responsibility for the integrity and accuracy of the research.

REFERENCES

- [1] A. Hammad and R. Abu-Zaid, "Applications of ai in decentralized computing systems: harnessing artificial intelligence for enhanced scalability, efficiency, and autonomous decision-making in distributed architectures," *Applied Research in Artificial Intelligence and Cloud Computing*, vol. 7, no. 6, pp. 161–187, 2024.
- [2] L. Cao, "Decentralized ai: Edge intelligence and smart blockchain, metaverse, web3, and desc," *IEEE Intelligent Systems*, vol. 37, no. 3, pp. 6–19, 2022.
- [3] N. P. L. Santoso, R. Nurmalia, and U. Rahardja, "Corporate leadership in the digital business era and its impact on economic development across global markets," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 6, no. 2, pp. 188–195, 2025.

- [4] R. Salama, S. Al-Turjman, C. Altrjman, F. Al-Turjman, R. Gupta, S. P. Yadav, and S. Vats, "Blockchain technology and artificial intelligence's future applications in cyber security," in *2023 3rd International Conference on Advancement in Electronics & Communication Engineering (AECE)*. IEEE, 2023, pp. 412–418.
- [5] A. Maariz, M. A. Wiputra, and M. R. D. Armanto, "Blockchain technology: Revolutionizing data integrity and security in digital environments," *International Transactions on Education Technology (ITEE)*, vol. 2, no. 2, pp. 92–98, 2024.
- [6] V. Shelake, S. Fernandes, and S. Shrugare, "Ai-driven personalized movie recommendations: A content and sentiment-aware model for streaming and digital entrepreneurship," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 2, pp. 306–317, 2025.
- [7] A. Garg, "Unified framework of blockchain and ai for business intelligence in modern banking," *International Journal of Emerging Research in Engineering and Technology*, vol. 3, no. 4, pp. 32–42, 2022.
- [8] K. P. Vittala, S. K. Arumugam, N. S. Kumar, and A. K. Tyagi, "Artificial intelligence: Blockchain integration for modern business," in *Advancing Software Engineering Through AI, Federated Learning, and Large Language Models*. IGI Global Scientific Publishing, 2024, pp. 87–104.
- [9] A. Abudaqa and I. Noburu, "Optimizing digipreneurship in the growth of the digital millennial creative economy ecosystem," *Startupreneur Business Digital (SABDA Journal)*, vol. 4, no. 1, pp. 24–34, 2025.
- [10] N. Louise, D. Andayani, E. A. Natalia, and S. Matondang, "Socialization of citizenship in cultivating the pancasila spirit among the community: Sosialisasi kewarganegaraan dalam menumbuhkan jiwa pancasila di kalangan masyarakat," *ADI Pengabdian Kepada Masyarakat*, vol. 5, no. 2, pp. 117–128, 2025.
- [11] L. Theodorakopoulos, A. Theodoropoulou, and C. Halkiopoulos, "Enhancing decentralized decision-making with big data and blockchain technology. a comprehensive review," 2024.
- [12] N. Lutfiani, Q. Aini, U. Rahardja, L. Wijayanti, E. A. Nabila, and M. I. Ali, "Transformation of blockchain and opportunities for education 4.0," *International Journal of Education and Learning*, vol. 3, no. 3, pp. 222–231, 2021.
- [13] F. Yusuf, R. Widayanti, S. R. Putri, and A. Wellington, "A comprehensive framework for enhancing blockchain security and privacy," *Blockchain Frontier Technology*, vol. 4, no. 2, pp. 171–182, 2025.
- [14] A. P. Balcerzak, E. Nica, E. Rogalska, M. Poliak, T. Klieštík, and O.-M. Sabie, "Blockchain technology and smart contracts in decentralized governance systems," *Administrative Sciences*, vol. 12, no. 3, p. 96, 2022.
- [15] I. Ahmed, Y. Zhang, G. Jeon, W. Lin, M. R. Khosravi, and L. Qi, "A blockchain-and artificial intelligence-enabled smart iot framework for sustainable city," *International Journal of Intelligent Systems*, vol. 37, no. 9, pp. 6493–6507, 2022.
- [16] K. Adel, A. Elhakeem, and M. Marzouk, "Decentralizing construction ai applications using blockchain technology," *Expert Systems with Applications*, vol. 194, p. 116548, 2022.
- [17] D. Andayani, J. F. Muhamad, N. Lutfiani, W. N. Wahid, and K. Moyo, "Enhancing transparency and efficiency in startupreneur development through blockchain enabled digital finance: Transparansi dan efisiensi pengembangan startupreneur pada keuangan digital berbasis teknologi blockchain," *ADI Bisnis Digital Interdisiplin Jurnal*, vol. 6, no. 1, pp. 1–11, 2025.
- [18] Y. Zuo, "Exploring the synergy: Ai enhancing blockchain, blockchain empowering ai, and their convergence across iot applications and beyond," *IEEE Internet of Things Journal*, 2024.
- [19] D. Bhumichai, C. Smiliotopoulos, R. Benton, G. Kambourakis, and D. Damopoulos, "The convergence of artificial intelligence and blockchain: The state of play and the road ahead," *Information*, vol. 15, no. 5, p. 268, 2024.

- [20] Q. Aini, D. Manongga, U. Rahardja, I. Sembiring, and Y.-M. Li, "Understanding behavioral intention to use of air quality monitoring solutions with emphasis on technology readiness," *International Journal of Human-Computer Interaction*, vol. 41, no. 8, pp. 5079–5099, 2025.
- [21] F. Ji and A. Tia, "The effect of blockchain on business intelligence efficiency of banks," *Kybernetes*, vol. 51, no. 8, pp. 2652–2668, 2022.
- [22] R. Royani, R. Fahrudin, A. F. Syatifa, and E. D. Astuti, "Impact of outcome-based education on graduate readiness in the era of globalization through international benchmarking: Pengaruh outcome-based education (obe) terhadap kesiapan lulusan di era globalisasi studi benchmarking internasional," *ADI Pengabdian Kepada Masyarakat*, vol. 5, no. 2, pp. 129–139, 2025.
- [23] C. Zheng, X. Tao, L. Dong, U. Zukaib, J. Tang, H. Zhou, J. C. Cheng, X. Cui, and Z. Shen, "Decentralized artificial intelligence in construction using blockchain," *Automation in Construction*, vol. 166, p. 105669, 2024.
- [24] M. Yusup, M. F. Ariq, E. J. A. H. Nasution, A. Z. Fahreza, and J. Edwards, "Digital transformation and branding for empowering the creative economy based on local wisdom: Transformasi digital dan branding untuk pemberdayaan ekonomi kreatif berbasis kearifan lokal," *ADI Bisnis Digital Interdisiplin Jurnal*, vol. 6, no. 1, pp. 45–54, 2025.
- [25] R. Wang, M. Luo, Y. Wen, L. Wang, K.-K. Raymond Choo, and D. He, "The applications of blockchain in artificial intelligence," *Security and Communication Networks*, vol. 2021, no. 1, p. 6126247, 2021.
- [26] A. R. Dina, N. Alifah, L. Paz *et al.*, "Leveraging big data for student success and institutional growth: Memanfaatkan big data untuk kesuksesan mahasiswa dan pertumbuhan institusi," *Jurnal MENTARI: Manajemen, Pendidikan dan Teknologi Informasi*, vol. 3, no. 2, pp. 147–156, 2025.
- [27] D. Darwish, "Blockchain and artificial intelligence for business transformation toward sustainability," in *Blockchain and its Applications in Industry 4.0*. Springer, 2023, pp. 211–255.
- [28] S. Anasuri, G. P. Rusum *et al.*, "Blockchain-based identity management in decentralized applications," *International Journal of AI, BigData, Computational and Management Studies*, vol. 3, no. 3, pp. 70–81, 2022.
- [29] V. Puri, A. Kataria, and V. Sharma, "Artificial intelligence-powered decentralized framework for internet of things in healthcare 4.0," *Transactions on Emerging Telecommunications Technologies*, vol. 35, no. 4, p. e4245, 2024.
- [30] H. H. Khanh and A. Khang, "The role of artificial intelligence in blockchain applications," in *Reinventing Manufacturing and Business Processes through Artificial Intelligence*. CRC Press, 2021, pp. 19–38.
- [31] S. Purnama, C. S. Bangun, and E. P. Mahadewi, "Predicting consumer purchase intention in personal shopper services using big data analytics and sem," *International Journal of Cyber and IT Service Management (IJCITSM)*, vol. 5, no. 1, pp. 105–119, 2025.
- [32] D. Martinez, L. Magdalena, and A. N. Savitri, "Ai and blockchain integration: Enhancing security and transparency in financial transactions," *International Transactions on Artificial Intelligence*, vol. 3, no. 1, pp. 11–20, 2024.
- [33] R. Haris, S. Duygulu, A. Hafidah, R. Syakur, B. Djatmiko, A. Maryam, and A. Indrawati, "Enhancing ecopreneurship competency through bidan elok e-learning based on local wisdom," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 2, pp. 424–440, 2025.
- [34] S. K. Rana, S. K. Rana, K. Nisar, A. A. Ag Ibrahim, A. K. Rana, N. Goyal, and P. Chawla, "Blockchain technology and artificial intelligence based decentralized access control model to enable secure interoperability for healthcare," *Sustainability*, vol. 14, no. 15, p. 9471, 2022.
- [35] V. Kersic and M. Turkanovic, "A review on building blocks of decentralized artificial intelligence," *arXiv preprint arXiv:2402.02885*, 2024.

- [36] I. Alim, N. Imtiaz, A. Al Prince, and M. A. Hasan, "Ai and blockchain integration: Driving strategic business advancements in the intelligent era," *Journal of Engineering and Computational Intelligence Review*, vol. 3, no. 2, pp. 38–50, 2025.
- [37] A. Sutarman, J. Williams, D. Wilson, and F. B. Ismail, "A model-driven approach to developing scalable educational software for adaptive learning environments," *International Transactions on Education Technology (ITEE)*, vol. 3, no. 1, pp. 9–16, 2024.
- [38] A. Ismail, A. R. Ismail, N. A. Shaharuddin, M. A. Ara, A. A. Puzi, S. Awang, and R. Ramli, "Vision-based vehicle classification for smart city," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 2, pp. 441–453, 2025.
- [39] I. Sasono and M. Aman, "Framework of master data management in banking using consolidation and jaro winkler algorithm," *International Journal of Cyber and IT Service Management (IJCITSM)*, vol. 5, no. 2, pp. 186–197, 2025.
- [40] S. Kumar, W. M. Lim, U. Sivarajah, and J. Kaur, "Artificial intelligence and blockchain integration in business: trends from a bibliometric-content analysis," *Information systems frontiers*, vol. 25, no. 2, pp. 871–896, 2023.
- [41] M. O. Joel, U. B. Chibunna, and A. I. Daraojimba, "Artificial intelligence, cyber security and block chain for business intelligence," *International Journal of Multidisciplinary Research and Growth Evaluation*, vol. 5, no. 1, pp. 1383–1387, 2024.
- [42] N. Lutfiani, N. Fauziyah, F. P. Oganda, R. Setyaningrum, E. A. Natalia *et al.*, "The role of globalization in indonesian evolution influence on media digital literacy language ai," *International Transactions on Artificial Intelligence*, vol. 3, no. 2, pp. 192–200, 2025.
- [43] E. Alaka, K. Abiodun, S. O. Jinadu, E. Igba, and V. N. Ezeh, "Data integrity in decentralized financial systems: A model for auditable, automated reconciliation using blockchain and ai," *International Journal of Management and Commerce Innovations*, vol. 13, no. 1, pp. 136–158, 2025.
- [44] M. Paramesha, N. Rane, and J. Rane, "Big data analytics, artificial intelligence, machine learning, internet of things, and blockchain for enhanced business intelligence," *Artificial Intelligence, Machine Learning, Internet of Things, and Blockchain for Enhanced Business Intelligence (June 6, 2024)*, 2024.
- [45] N. Lutfiani, I. Sembiring, I. Setyawan, A. Setiawan, U. Rahardja, and S. Sulistio, "Exploring the relationship between artificial intelligence and business performance," *IJCCS (Indonesian Journal of Computing and Cybernetics Systems)*, vol. 19, no. 1, pp. 1–12, 2025.
- [46] H. Taherdoost, "Blockchain technology and artificial intelligence together: a critical review on applications," *Applied Sciences*, vol. 12, no. 24, p. 12948, 2022.
- [47] T. R. Xuan and S. Ness, "Integration of blockchain and ai: exploring application in the digital business," *Journal of Engineering Research and Reports*, vol. 25, no. 8, pp. 20–39, 2023.
- [48] A. M. Adebowale and O. B. Akinagbe, "Leveraging ai-driven data integration for predictive risk assessment in decentralized financial markets," *Int J Eng Technol Res Manag*, vol. 5, no. 12, p. 295, 2021.
- [49] J. Siswanto, V. A. Goeltom, I. N. Hikam, E. A. Lisangan, and A. Fitriani, "Market trend analysis and data-based decision making in increasing business competitiveness," *Sundara Advanced Research on Artificial Intelligence*, vol. 1, no. 1, pp. 1–8, 2025.
- [50] N. Rane, S. Choudhary, and J. Rane, "Blockchain and artificial intelligence (ai) integration for revolutionizing security and transparency in finance," *Available at SSRN 4644253*, 2023.
- [51] D. Patel, C. K. Sahu, and R. Rai, "Security in modern manufacturing systems: integrating blockchain in artificial intelligence-assisted manufacturing," *International Journal of Production Research*, vol. 62, no. 3, pp. 1041–1071, 2024.