

Governance, Security, and Emerging Applications of Decentralized Autonomous Organizations: A Systematic Review

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Abstract: Decentralized Autonomous Organizations (DAOs) employs blockchain and smart contracts to support transparent, community-driven governance. Despite growing adoption of DAOs across finance, healthcare, supply chains, and digital communities, however research in this space remains scattered. This systematic review synthesizes recent DAO research using a PRISMA methodology, drawing from 158 publications (2018–2026) across six databases, with 51 peer-reviewed studies selected for analysis. Four key themes emerge: governance models, voting mechanisms, smart contract security, and interdisciplinary applications. Recurring challenges include voting power concentration, participation inequality, governance fatigue, and regulatory uncertainty. The review identifies emerging research opportunities, including inclusive governance frameworks, adaptive participation models, and automated smart contract auditing. These directions establish a roadmap for future research toward developing secure, transparent, and sustainable DAO ecosystems.

Keywords: Decentralized Autonomous Organizations (DAOs), Blockchain Governance, Smart Contracts, Consensus Mechanisms, Decentralized Governance, Voting Mechanisms, Governance Security

Introduction

Decentralized Autonomous Organizations (DAOs) represent a transparent governance structure within blockchain ecosystems, allowing communal decision-making through smart contracts rather than centralized authorities [1]. Their application has expanded well beyond cryptocurrency and DeFi into healthcare, supply chains, sustainability, and decentralized science, placing DAOs as a useful model for digital coordination [2], [3]. Despite their increasing adoption, practical governance remains challenging. Widely used Token-based models suffer from voting concentration, participation inequality, and governance fatigue, raising concerns about long-term sustainability [4]. Security remains a significant challenge affecting reliability and sustainability. Smart contract vulnerabilities have shown that decentralization alone does not ensure safe organizational management [1]. As DAO research continues to expand, the literature has become fragmented across governance architectures, voting mechanisms, security practices, and application domains. This study addresses that gap through a systematic review of DAO governance mechanisms, examining existing models, participation structures, smart contract security challenges, and developing applications identifying key research gaps and future research directions for secure, adaptive, and scalable DAO ecosystems.

Review Methodology

This work employs a systematic literature review to study DAO governance mechanisms, following a structured process designed for transparency and reproducibility. Searches were conducted across six academic databases including Scopus, Web of Science, IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar using keyword combinations such as "Decentralized Autonomous Organization," "DAO Governance," "Blockchain Governance," "Smart Contracts," "Decentralized Voting," and "Governance Security," connected through Boolean AND/OR operators. Only peer-reviewed journal articles and conference papers published in English between 2018 and 2026 were considered. Studies were included if they addressed DAO governance, voting mechanisms, smart contract security, or interdisciplinary applications. Non-peer-reviewed content, editorials, duplicates, and unrelated publications were excluded. As illustrated in Figure 1, selection followed a multi-stage screening process. From 158 initially identified records, 32 duplicates were removed, leaving 126 studies for screening. After excluding 55 records based on title and abstract review, 71 full-text articles were assessed for eligibility. A further 20 were excluded, resulting in 51 studies retained for thematic analysis covering governance models, participation structures, security challenges, and emerging DAO application domains.

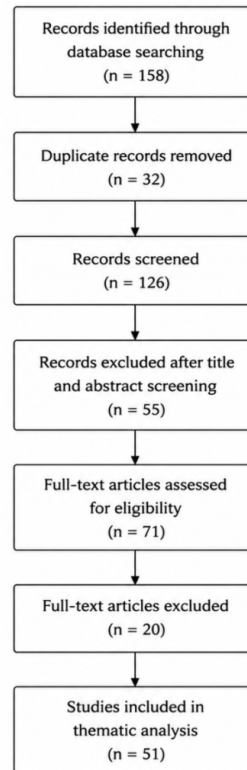


Figure 1. PRISMA Flow Diagram Illustrating the Study Selection Process

Thematic Analysis of DAO Governance Research

The reviewed literature reflects a notable growth in DAO research, driven by the expanding use of blockchain-based governance across multiple sectors. Reviewed literature is divided into four themes as governance models, voting and participation mechanisms, security and smart contract challenges, and emerging applications. These themes collectively illustrate how DAOs are structured, governed, secured, and deployed in real-world environments. The following subsections illustrate the key findings from the

reviewed studies and highlight major opportunities and challenges associated with each research theme [7], [8], [9], [10].

Governance Models in Decentralized Autonomous Organizations

Governance is the mechanism through which DAOs synchronize activities, allocate resources, and support collective decision-making among distributed members. Unlike traditional organizations that rely on centralized hierarchical structure, DAOs encode organizational rules into smart contracts executed transparently across decentralized networks, moving control toward community-driven management [7], [8]. Early DAO governance depend on heavily on token-based voting, where token ownership determined decision rights in proposal and approval processes. However, research has shown that effective governance extends beyond token holdings, requiring stakeholder incentive alignment and transparent processes [8], [9]. Despite the decentralized structure, governance influence frequently concentrates among large token holders that weaken democratic principles [9]. In avoid this, researchers have proposed alternative frameworks stressing equitable representation and broader stakeholder accountability. Research shows that effective DAO governance requires a balance between clear governance rules and active participation from community members. Blockchain and smart contracts help enforce these rules securely and transparently, while community involvement encourages collaboration and accountability among stakeholders. When combined, these elements strengthen governance outcomes and support the long-term sustainability of DAOs [10]. Overall, governance remains central to DAO effectiveness and long-term sustainability. Persistent challenges around voting concentration, participation inequality, scalability, and organizational resilience continue to demand attention, and addressing them will be critical to building more adaptive and robust DAO ecosystems [7], [8], [9], [10]. Table 1 summarizes the key governance models identified across the reviewed studies, highlighting their core characteristics and associated challenges.

Table 1. Comparison of Governance Models in DAOs

Governance Model	Governance Basis	Advantages	Limitations
Token-Based Governance [8], [9]	Voting power proportional to token ownership	Transparent, easy implementation, broad accessibility	Voting concentration and dominance of large token holders
Reputation-Based Governance [7], [10]	Voting rights tied to participant reputation and contributions.	Encourages participation and long-term commitment	Reputation assessment and maintenance complexity
Delegated Governance [8], [9]	Participants assign their voting rights to trusted delegates.	Improved decision-making efficiency and participation	Potential centralization of influence among delegates
Hybrid Governance [7], [10]	Combines token, reputation, and delegated mechanisms	Balances inclusiveness, efficiency, and governance flexibility	Increased implementation and management complexity

Voting and Participation Mechanisms

Voting mechanisms define how participants exercise influence within DAOs. Token-based voting is the most common approach, where power depends on tokens held, but it brings notable drawbacks

including low turnout, disengagement, and dominance by large token holders [11], [12]. Alternative models such as reputation-based voting, delegated voting, and hybrid approaches have since emerged to encourage wider and fairer participation [11]. Participation is shaped by financial incentives, governance complexity, and community involvement. A recurring problem is governance fatigue, where members gradually lose interest in voting over time, weakening decentralization and long-term sustainability [12]. Research further highlights that participation quality matters as much as quantity, with Li et al. [13] noting that informed engagement produces better governance outcomes than passive involvement. Despite ongoing improvements, unequal participation, voter disengagement, and decision quality remain key challenges requiring further investigation [11], [12], [13]. Table 2 presents a comparative overview of key voting mechanisms identified in the literature, along with their respective advantages and disadvantages.

Table 2. Comparison of Voting Mechanisms in DAOs

Voting Mechanism	Basis of Voting Power	Advantages	Limitations
Token-Based Voting	Number of governance tokens held	Simple, transparent, widely adopted	Voting concentration, whale dominance
Reputation-Based Voting	Community contribution and reputation	Encourages expertise and commitment	Difficult reputation evaluation
Delegated Voting	Voting rights assigned to delegates	Improved participation and efficiency	Risk of delegate centralization
Hybrid Voting	Combination of multiple mechanisms	Balanced governance structure	Implementation complexity

Security and Smart Contract Challenges

Security is a serious issue for DAOs because they rely on smart contracts to handle governance, funds, and operations. Without centralized coding, any coding errors, logical flaws, or access control weaknesses can directly lead to financial losses or manipulation of governance processes. Common threats include reentrancy attacks, integer overflow errors, and unauthorized contract interactions, all of which can damage stakeholder trust [14], [16]. Governance mechanisms themselves can also be targeted. Attackers may accumulate tokens or coordinate voting behavior to gain outsized control over decisions, effectively undermining the decentralized nature of the organization [16]. Studies by Hejazi and Lashkari [14] and Patil et al. [15] point to automated vulnerability detection and regular smart contract audits as practical measures that improve security and reduce operational risk, and both argue that such checks should happen during development of smart contracts. DAOs need to employ mechanisms like formal verification and continuous monitoring with stronger governance safeguards to remain secure and trustworthy as they take on greater responsibility for managing funds and community resources [14], [15], [16].

Table 3. Security Challenges and Mitigation Approaches in DAOs

Security Challenge	Potential Impact	Mitigation Approach
Smart Contract Vulnerabilities [14], [16]	Financial loss and operational disruption	Formal verification and code auditing
Governance Manipulation [16]	Unfair decision outcomes	Transparent voting and governance controls

Access Control Weaknesses [14], [15]	Unauthorized actions	Role-based permissions and security audits
Malicious Contract Interactions	Contract exploitation and asset theft	Continuous monitoring and vulnerability assessment

Emerging Applications of Decentralized Autonomous Organizations

Beyond cryptocurrency and DeFi, DAOs are finding increasing adoption across healthcare, sustainability, supply chain management, and public sector governance. In healthcare, Cunningham et al. [17] showed how DAO governance can support secure and transparent management of medical data, giving stakeholders collective control over access rights and data sharing without relying on central authorities. In sustainability, Asif et al. [18] noted that blockchain-based governance can strengthen ESG reporting by improving data reliability and accountability, with DAOs enabling decentralized verification of sustainability activities. Similar opportunities have been identified in supply chains and digital communities, where automated governance reduces administrative burden while improving transparency [19]. Research also suggests that DAO governance frameworks could serve as blueprints for future digital organizations more broadly. Patil et al. [20] found that structured decision-making and transparent participation frameworks support the sustainable operation of blockchain-based organizations. That said, practical barriers around scalability, regulatory compliance, interoperability, and user adoption still need to be worked through before DAOs can achieve wider and more lasting implementation across these domains [17], [18], [19], [20].

Research Gaps and Future Directions

Despite growing research on DAOs, key challenges remain around governance effectiveness, participation, and security. Voting power concentration, participation imbalances, and governance fatigue continue to limit the fairness and sustainability of decentralized decision-making [9], [11], [12], [13]. Smart contract vulnerabilities and governance manipulation further expose DAOs to financial and operational risks, and while auditing tools have improved, scalable security frameworks are still lacking [14], [15], [16]. Emerging DAO applications in healthcare, sustainability, and supply chain management show strong potential, yet large-scale empirical evidence remains thin [17], [18], [19], [20]. Table 4 outlines the key research gaps identified across the reviewed literature along with corresponding research directions.

Table 4. Research Gaps and Future Research Directions

Research Area	Identified Gap	Future Research Direction
Governance Models	Voting power concentration and representation imbalance	Development of fair and inclusive governance frameworks
Participation Mechanisms	Low stakeholder engagement and governance fatigue	Incentive-driven and adaptive participation models
Security and Smart Contracts	Vulnerabilities, governance attacks, and audit limitations	Automated auditing, formal verification, and continuous monitoring
Emerging Applications	Limited real-world implementation evidence	Cross-sector empirical studies and deployment frameworks
Sustainability and Digital Governance	Limited integration of DAO governance with ESG initiatives	Decentralized governance models for sustainability and transparency

Conclusion

This review examined DAO governance across four themes: governance models, voting mechanisms, smart contract security, and emerging applications. While DAOs offer clear advantages in transparency, automation, and community participation, challenges around governance concentration, participation inequality, security vulnerabilities, and large-scale adoption persist. Future research should prioritize inclusive governance frameworks, stronger security practices, and broader cross-domain implementation to support the sustainable development of decentralized organizational ecosystems.

References

1. S. Hassan and P. De Filippi, "Decentralized Autonomous Organization," *Internet Policy Review*, vol. 10, no. 2, pp. 1–10, 2021, doi: 10.14763/2021.2.1556.
2. F. Schär, "Decentralized Finance: On Blockchain- and Smart Contract-Based Financial Markets," *Federal Reserve Bank of St. Louis Review*, vol. 103, no. 2, pp. 153–174, 2021, doi: 10.20955/r.103.153-74.
3. S. Bonnet and N. Naous, "Decentralized Autonomous Organizations (DAOs): A Systematic Literature Review and Research Agenda," *International Journal of Information Technology & Decision Making*, vol. 23, no. 6, 2024, doi: 10.1142/S0219877024500263.
4. P. Tolmach, Y. Li, S.-W. Lin, Y. Liu, and Z. Li, "A Survey of Smart Contract Formal Specification and Verification," *ACM Computing Surveys*, vol. 54, no. 7, pp. 1–38, 2022, doi: 10.1145/3464421.
5. M. J. Page et al., "The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews," *BMJ*, vol. 372, p. n71, 2021, doi: 10.1136/bmj.n71.
6. B. Kitchenham and S. Charters, *Guidelines for Performing Systematic Literature Reviews in Software Engineering*, EBSE Technical Report, Keele University and Durham University, 2007.
7. D. Wegner, R. D. Zuquetto, and F. C. Grisi, "Decentralized Autonomous Organizations (DAOs): Field of Research and Avenues for Future Studies," *BAR - Brazilian Administration Review*, vol. 21, no. 2, 2024, doi: 10.1590/1807-7692bar2024230183.
8. N. Augustin, A. Eckhardt, and A. W. De Jong, "Understanding decentralized autonomous organizations from the inside," *Electronic Markets*, vol. 33, no. 1, 2023, doi: 10.1007/s12525-023-00659-y.
9. O. Rikken, M. Janssen, and Z. Kwee, "Governance impacts of blockchain-based decentralized autonomous organizations: an empirical analysis," *Policy Design and Practice*, vol. 6, no. 4, pp. 465–487, 2023, doi: 10.1080/25741292.2023.2270220.
10. A. Alawadi, N. Kakabadse, A. Kakabadse, and S. Zuckerbraun, "Decentralized autonomous organizations (DAOs): Stewardship talks but agency walks," *Journal of Business Research*, vol. 178, 2024, doi: 10.1016/j.jbusres.2024.114672.
11. Y. Fan, L. Zhang, R. Wang, and M. A. Imran, "Insight Into Voting in DAOs: Conceptual Analysis and a Proposal for Evaluation Framework," *IEEE Network*, vol. 38, no. 3, pp. 92–99, 2024, doi: 10.1109/MNET.137.2200561.
12. T. Sharma et al., "Unpacking How Decentralized Autonomous Organizations (DAOs) Work in Practice," in *IEEE ICBC*, 2024, pp. 416–424, doi: 10.1109/ICBC59979.2024.10634404.
13. J. Li, R. Qin, S. Guan, W. Ding, F. Lin, and F.-Y. Wang, "Attention Markets of Blockchain-Based Decentralized Autonomous Organizations," *IEEE/CAA Journal of Automatica Sinica*, vol. 11, no. 6, pp. 1370–1380, 2024, doi: 10.1109/JAS.2024.124491.
14. N. Hejazi and A. H. Lashkari, "A Comprehensive Survey of Smart Contracts Vulnerability Detection Tools: Techniques and Methodologies," *Journal of Network and Computer Applications*, vol. 237, p. 104142, 2025, doi: 10.1016/j.jnca.2025.104142.

15. R. V. Patil, I. S. Borse, M. P. Patil, A. H. Khadke, G. M. Poddar, and S. R. Patil, "Ensuring Trust in Blockchain Enabled Business Processes using Smart Contract Audits," in 2025 International Conference on Inventive Computation Technologies (ICICT), IEEE, 2025, pp. 1248–1254, doi: 10.1109/ICICT64420.2025.11004761.
16. D. He, Z. Deng, Y. Zhang, S. Chan, Y. Cheng, and N. Guizani, "Smart Contract Vulnerability Analysis and Security Audit," IEEE Network, vol. 34, no. 5, pp. 276–282, 2020, doi: 10.1109/MNET.001.1900656.
17. J. Cunningham et al., "The application of distributed autonomous organization governance mechanisms to civic medical data management," IET Blockchain, vol. 4, no. S1, pp. 507–525, 2024, doi: 10.1049/blc2.12062.
18. M. Asif, C. Searcy, and P. Castka, "ESG and Industry 5.0: The role of technologies in enhancing ESG disclosure," Technological Forecasting and Social Change, vol. 195, p. 122806, 2023, doi: 10.1016/j.techfore.2023.122806.
19. C. Santana and L. Albareda, "Blockchain and the emergence of Decentralized Autonomous Organizations (DAOs): An integrative model and research agenda," Technological Forecasting and Social Change, vol. 182, p. 121806, 2022, doi: 10.1016/j.techfore.2022.121806.
20. R. Patil, S. K. Swarnkar, D. Y. Bhadane, G. M. Poddar, M. P. Patil, and R. C. Sonawane, "Exploring Governance Frameworks and Decision Processes in Blockchain-Based Decentralized Autonomous Organizations," International Journal of Basic and Applied Sciences, vol. 14, no. 1, pp. 166–180, 2025, doi: 10.14419/h0y6dw98.